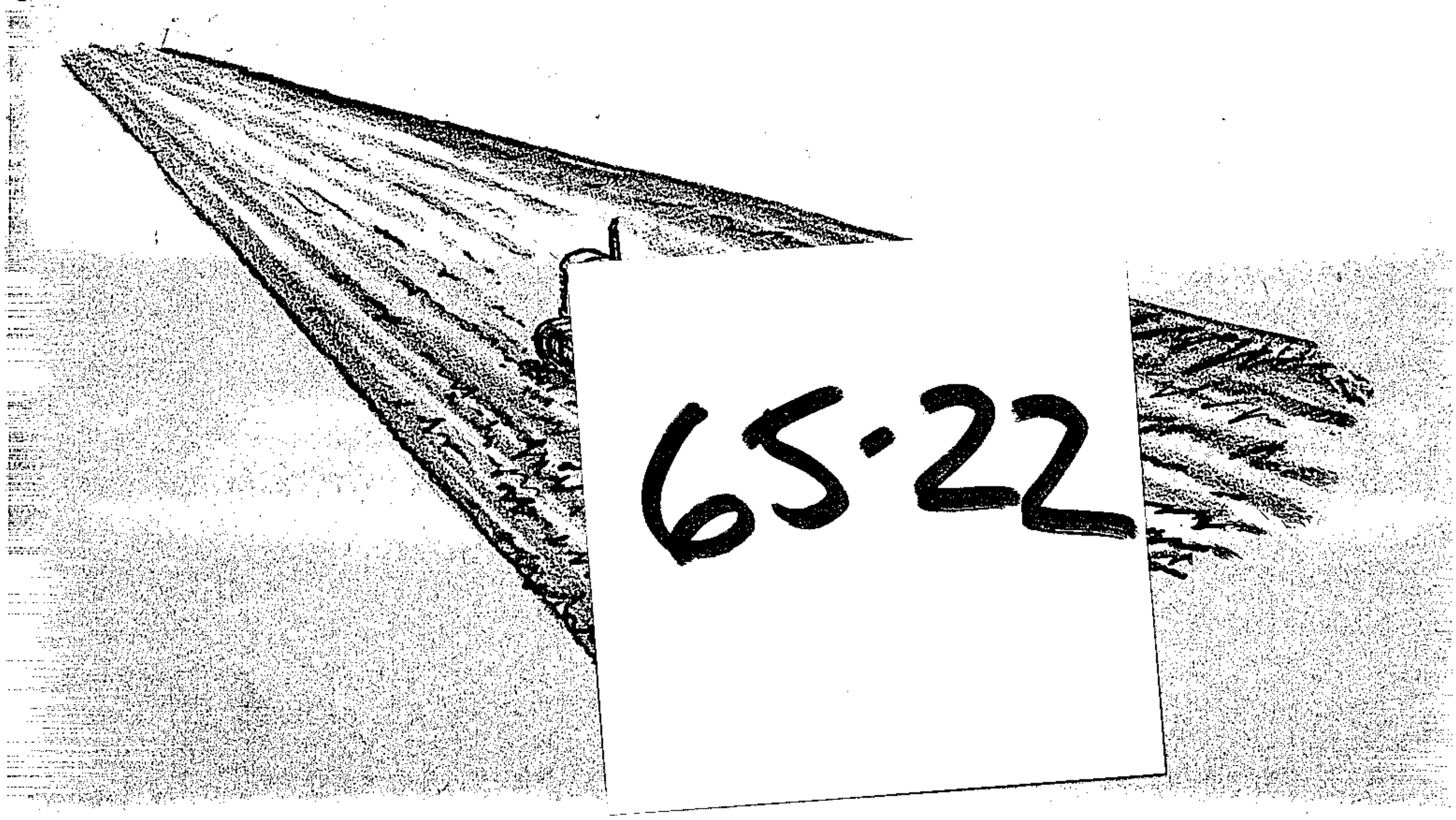
H105

Field Evaluation of the Lane-Wells Road Logger



MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

June 9, 1965

Lab Auth 24620

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

REPORT

of

FIELD EVALUATION

of the

LANE-WELLS ROAD LOGGER

Study made by .... Foundation Section
Under general direction of ...... Travis Smith
Work supervised by .... W. G. Weber, Jr.
Field work by .... J. Puleo
Report prepared by .... J. Puleo
R. E. Smith

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

cc: LR Gillis
JF Jorgensen
AC Estep

FOREWORD

The determination of the density and moisture in highway construction is of concern in present-day construction. A new piece of equipment has been developed that records the moisture and density of soils by nuclear methods while driving the unit over the soil. This equipment is referred to as the Lane Wells Road Logger.

This research project was to evaluate the Road Logger. Limited laboratory work was performed to determine the depth to which the nuclear readings were being made. The principal portion of the work consisted of making field readings and evaluating the performance of the Road Logger. Correlation tests between the nuclear and conventional tests were also conducted in the field.

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ACKNOWLEDGEMENTS

The following study was performed by the Foundation Section of the Materials and Research Department of the California Division of Highways. The program was financed with Bureau of Public Roads 1½ percent research funds. Nine of the California Highway Districts cooperated in the field portion of this study.

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ABSTRACT

The Road Logger, a truck-mounted nuclear gage for determining soil moisture and density, was evaluated for its potential use in compaction control. This equipment produces a continuous chart giving the soil moisture and density as the truck is driven over the compacted embankment. The data from the Road Logger was comparable in accuracy to the sand volume test. There was some sensitivity of the Road Logger to the surface condition in embankment materials and no surface effect on subgrade, base and similar materials. The indications are that there exists a definite potential for the use of the Road Logger in compaction control. The economic advantage of the use of the Road Logger is questionable on small contracts, but there may be some advantage when used on several large contracts. As the Road Logger obtains a large number of tests rapidly a new approach to the utilization of this data is presented. It is proposed to try the Road Logger on a construction project as the means of acceptance of compaction of earth materials.

Introduction

In the Fall of 1964 an evaluation of the potential use of the Lane Wells Road Logger in compaction control was undertaken jointly by the Materials and Research Department and Construction Department of the California Division of Highways.

The Road Logger is a truck-mounted nuclear gage that produces a continuous recording of the moisture and density of the material over which the truck travels. The recording is in the form of a strip chart.

The Road Logger was used on 28 construction projects in nine districts for periods varying from one to five days per project. The operation of the Road Logger on the various projects was noted in respect to characteristics, deficiencies, and limitations. Limited correlation testing with standard testing procedures was undertaken. The potential use of the Road Logger in compaction control was evaluated, and the economics of this device studied. The evaluation of the Road Logger is contained in this report.

This project was financed with BPR 1½ percent research funds.

Results and Conclusions of Evaluation

This evaluation study indicates that it is feasible to use the Road Logger in compaction control. The Road Logger would have to be used on the equivalent of two or three projects to economically justify its use. Embankments can be tested without serious difficulty and the structural section materials tested quite readily without prior preparation.

There are several limitations in the use of the Road Logger. In embankment construction it is necessary to blade the surface of the fill where sheepsfoot rollers are used, but no surface preparation is necessary where pad, rubber tired, and vibratory rollers are used. On rocky fills the speed of travel must be reduced to avoid excessive vibration of the equipment, however, this would only result in less mileage being logged per day. Several mechanical defects in the equipment were noted, however, it is felt that as the manufacturer "debugs" the equipment these defects will be eliminated.

It appears that three to seven miles of log can be obtained in a normal day's operation. This results in an infinite number of readings and would require a modification of our present approach for interpretation. When uniform soil conditions are encountered this would present only a minor problem. It would be practical to define compliance in terms of assuring the frequency distribution of the in-place densities are within the frequency distribution of the values found for the test maximum densities. This relationship could be expressed in empirical terms for field application. However, in hetrogeneous soil

conditions, where variable minimum acceptable densities occur, a problem exists in interpreting the data obtained with the Road Logger. At the present time it would be necessary to classify the material as it is logged and use various minimum acceptable densities as indicated by the visual classifications. Where processed materials are being used, such as in the structural section, the interpretation of the data would be easily accomplished.

At the start of the program considerable doubt existed as to the practicability of using the Road Logger on embankments. Subbase, base, and similar materials are uniform materials with reasonably smooth surfaces, and little difficulty was expected with these types of materials. In actual use the Road Logger performed moderately well on embankment materials, except where sheepsfoot rollers were used for compaction. It appears that the main reason that the Road Logger performed so well is the large volume of soil that was tested. Under normal testing speeds and time constant, a volume of about six cubic feet is being measured. Minor variations such as rocks, variation in air gap, and surface roughness did not affect the readings as had been anticipated. The depth of the soil affecting the nuclear readings was five to seven inches and the portion of the soil nearest the gage did not greatly affect the readings as with the portable gages. The use of the Road Logger in most embankment construction appears feasible.

The Road Logger requires considerable space in which to operate. It was impossible to conduct tests in limited areas such as structural backfill. The manufacturer is planning to provide a portable gage that will operate off the Road Logger's electronic system to overcome this deficiency.

The correlation of the sand volume and nuclear tests was good. The standard deviation of the nuclear densities compared to the sand volume tests was three pounds per cubic foot. Four sand volume tests were obtained for each nuclear test. This resulted in less than one cubic foot in volume being measured by the sand volume tests against six cubic feet with the nuclear test. The standard deviation of the four sand volume tests about their average was two pounds per cubic foot. It thus appears that the nuclear densities are approaching the accuracy of the sand volume tests. The standard deviation of the nuclear moistures compared to the oven dried moistures was one and one-half pounds of water per cubic foot. It appears that the nuclear readings are sufficiently accurate for compaction control.

This evaluation study has provided information on many aspects of the Road Logger. However, there are certain aspects of the use of the Road Logger that can only be evaluated by actual use on a construction project. It is, therefore, recommended that the Road Logger be used as the method of determining in-place density on an entire construction project or projects. It would be desirable to use the Road Logger on two projects in a reasonable radius to obtain information as to its full potential coverage and economic

use. This would also enable an evaluation of the proposed method of using the Road Logger data in compaction control. This evaluation has indicated that the accuracy and practicability of the use of the Road Logger is sufficient to continue the study of the use of this equipment.

History

A demonstration of the Road Logger was given in Los Angeles on January 29 - 30, 1964, by the Lane Wells Co. This demonstration was witnessed by personnel from the Headquarters Design, Construction, Materials and Research Departments and by District 07 personnel. This demonstration was reported in a memo to T. W. Smith from W. G. Weber dated February 5, 1964. The results of this demonstration indicated that it might be feasible to use the Road Logger in compaction control. Oklahoma Division of Highways has been using the Road Logger for compaction control of the structural section material, however, they had not used it in embankments.

A conference was held on April 2, 1964, with representatives of the Construction, Design, and Materials and Research Departments present. A representative of the Lane Wells Company was also present. At this meeting it was decided to recommend that an evaluation program of the Road Logger be undertaken. The evaluation was to be primarily a field program using the Road Logger on current construction projects. It was desired to determine if the Road Logger can profitably be used in highway construction, the limitations of the Road Logger, and how the data obtained by the Road Logger can be interpreted properly.

The use of Federal 1½ percent research funds were requested for this project. Formal Federal approval for the project was obtained May 20, 1964, from the Bureau of Public Roads, Item D.1.2 of Federal Work Program HPR 1 (2) for 1964-65 fiscal year.

The Road Logger was received on August 18, 1964, and the laboratory phase of the study started.

Description of the Road Logger

The Road Logger is essentially a truck-mounted nuclear gage. Due to the nuclear methods utilized in this device large radioactive sources are used. These sources require about 450 pounds of lead shielding. Complicated electronics are required for the detector system used. As a result, the nuclear and electronic components are much too heavy to be considered portable. This is the reason that these components are permanently mounted on a truck. The nuclear and electronic components are very highly refined, compared to the present portable gages.

The nuclear components consist of two sensors, one for density and one for moisture. Due to radiation considerations these two sensors are separated by a distance of ten feet so

that one sensor does not influence the other one. This requires one sensor to be mounted in the truck and one in a trailer. The sensors are mounted on two wheels and this unit is hydraulically raised from the logging to the traveling position and vice versa. The air gap between the bottom of the sensor and the surface of the soil is maintained at one inch. The air gap setting must be checked each time the sensors are lowered to the logging position.

The density sensor is of the backscatter type using a cobalt 60 source of 0.45 curies that is highly collimated. The density detector is a three-inch sodium iodide crystal that is set to record only the gamma rays above about 0.2 million electron volts. The manufacturer feels that the combination of the five-inch collimation, one-inch air gap, and energy discrimination will: increase depth of penetration, remove predominence of surface soil layer on nuclear counts, and enable one calibration for all soils. The three items above are where the Road Logger density sensor differs from the portable density gages.

The moisture sensor uses a five-curie plutonium-beryllium source and four boron trifloride detector tubes. This moisture sensor is similar to the portable moisture gages.

The electronic system is the rate meter type with a recorder attached. The number of pulses received from the detector increases the voltage across a condensor and this voltage is being continuously bled off the condensor by a resistor. This voltage then operates the recorder. By varying the condensor and resistor values the time constant can be varied. The time constant of the system is the time for the voltage across the condensor to become stable with a change in input pulses. In all work done in this evaluation program a time constant of three seconds was used. Time constants of one and five seconds are also provided in the electronic system. However one second time constant produces a sensitive condition where the system responds to minor density variations, and the five second time constant produces a stable condition where the system fails to respond to normal density variations. The three second time constant used is a compromised value. The portable gages use a scaler that counts the number of pulses in a given time interval.

The electronics used in the Road Logger are high quality standard components. These are required because of the rate meter system being used. Due to this refined equipment greater training of the operator is required than with the portable gages. It is suspected that the maintenance costs would also be greater with the Road Logger, however, the leasing arrangements make this the responsibility of the Lane Wells Co.

The speed of travel of the truck in the logging position can be varied from about 50 to 200 feet per minute. This is done through a governor on the engine. The combination of the speed of the vehicle and the time constant determine the length of soil being averaged on the chart.

Evaluation Program

Upon delivery of the Lane Wells Road Logger to the Materials and Research Laboratory, a limited study was made of the effective depth of measurement of the density sensor.

A rectangular wooden ring-mold progressively assembled upon a 48 x 36 x 2 in. steel plate was used in the study. A nuclear reading was first taken on the bare steel plate, after which two wooden rings 1 in. high were firmly attached to it. A given weight of soil was evenly spread in the shallow mold and pressed into place with a plywood board as the first step in the compaction process. A 10-lb. drop hammer fitted with a 4-in. square steel plate was used to finish the compaction of the soil. The topmost ring was then removed to facilitate the using of a straight edge to strike the soil surface level with the top of the next lower ring. A nuclear reading was taken on the resulting soil surface, Photo 51. The procedure was repeated in 1 in. increments until the nuclear readings no longer changed with the increased height of soil sample.

Upon completion of the depth study the surface was grooved one-half inch in depth and one inch from center to center of the grooves. Nuclear measurements were then taken on the altered surface to determine the effect of the surface roughness on the nuclear device.

The field crew, consisting of four to five men, commenced the field operation August 26, 1964 at the 29th and 30th St. freeway in Sacramento. At this project embankment was logged and two sand volume versus nuclear correlations were performed.

The procedure used in all correlation studies is as follows: A specific area on the logging chart would be noted as having a uniform density. This area would then be marked with paint, Photo 40, and the moving and static nuclear readings would be taken, Photo 49. Usually four sand volumes were taken about a foot and a half apart along the longitudinal axis of the site.

On the 27th of August more embankment on the Sacramento freeway was logged and two more correlations were taken. The material was imported borrow of sandy clay classification.

August 28, the nuclear unit was taken to El Dorado Hills where embankment of rocky clay was logged and a correlation was taken.

On August 31 and September 1 the Road Logger was used on aggregate base and cement treated base at Pollock Pines. There two correlations were taken involving the nuclear unit, the sand volume, and a water volume.

The water volume consisted of one large hole, about the same volume as the four sand volumes combined. This hole was then lined with a thin plastic sheet and water poured into the top of the hole.

September 2 and 3 the Road Logger was at Salinas where the density and moistures of embankment, subgrade and foundation material of silty sand classificiation was determined.

At Cupertino on September 11 and 14 the moisture and density of silty clay material on embankment and subgrade was determined with the Road Logger. Four correlations were taken.

On September 14 the Lane Wells Company representatives replaced the Model M1065 (Photo 2, 3) Road Logger with an improved model (M1093, Photo 1).

The following day the new Road Logger was taken to San Jose and moisture and density of cement treated base was obtained and two correlations taken.

The Road Logger spent the next five days at Dublin obtaining moisture and density readings on silty clay embankment and foundation soils with four correlation studies made. Also concrete pavement was logged and a correlation was made.

The Road Logger was moved to Tracy where, on September 24 and 25, a subgrade of silty clay was studied and two correlations were taken. While at Tracy a limited investigation was performed, to determine how critical a variation in air gap is, by noting the changes in the recorded density of static tests as the air gap was varied.

With the Lane Wells Road Logger parked at the Tracy airport on a concrete slab the air gap between the density sensor and the surface of the slab was varied in 1/8 in. increments. The trial began with a 1/2 in. clearance which was progressively increased to an air gap of 1½ inches.

At Modesto on September 28 the moisture and density of concrete pavement and cement treated base was determined with two sand volume versus nuclear comparisons made on the cement treated base.

Two days were spent at Mettler where four correlations were made on silty sandy clay subgrade and foundation material.

On October 2 and 3 the moisture and density of a decomposed granite subgrade was obtained at Tehachapi. Two correlations were performed then. While at Tehachapi a study was made to determine the repeatability of the nuclear measurements. These were performed by fixing a rigid bar to the front bumper of the Road Logger, from it a length of chain was hung, the operator then followed a painted line on the grade with the chain.

At Barstow, October 6 and 8, six correlation studies were made on a gravelly sand subgrade. Near Barstow, on soft desert alluvium, another study was made to determine the effect of variation in air gap. The procedure followed was similar to the above mentioned at the Tracy Airport.

On October 13 and 14 at El Cajon the Road Logger was used on silty clay embankment and subgrade with two sites for the correlation study.

At Del Mar on October 15 and 23 three sites were used for the correlation and the moisture and density of a subgrade of silty sand was obtained with the Road Logger. On October 16 at Del Mar a study was made of the effect of various logging speeds. The same alignment control was used as mentioned in the repeatability study, but each pass with the nuclear device had a different logging speed.

On October 19 at Jacumba the moisture and density of a cement treated base was obtained and two correlations were taken on decomposed granite subgrade.

The moisture and density of rocky clay embankment at Poway was obtained and two sites were used for the correlation study on October 20. On this day also another study at various logging speeds was performed. On October 22 at Poway a repeatability study was made. The procedure was the same as that at Tehachapi except twine was fastened to the ground instead of painting a line.

In National City on October 21 the unit was used to obtain the density of concrete pavement, asphaltic concrete pavement and cement treated base.

At Palmdale on October 27 and 28 the Road Logger was used in a brief study on the effect of rolling.

Immediately after the placement of a lift of material four passes were made with the segmented roller, then the area was logged with the nuclear unit.

At Calabasas on October 29 a study was made on the effect of blading an area prior to logging. A certain area was logged, then it was bladed, followed closely by another logging run.

On October 30 at Saticoy the moisture and density of a subgrade of silty sand was obtained and one correlation taken.

On two projects on the new Pomona Freeway on November 3 and 4, the Road Logger was used on two correlation test sites on silty sand and silty clay subgrade and embankment.

On the San Gabriel Freeway on November 5 and 6 the moisture and density of a silty clay subgrade and embankment was obtained with the Road Logger and two correlation studies made.

On November 13 the Road Logger was sent to Cordelia to log embankments consisting of volcanic tuff, and rocky clay.

The unit was used on the 16th at El Centro Road on asphalt concrete placed over various bases. Logging runs were made in the wheel tracks produced by traffic, and again between the wheel tracks.

The logging operation of the 17th was at Pollock Pines and was divided between cement treated base and asphalt pavement. Two core samples were taken from the asphalt concrete pavement and were compared to the nuclear density of the Lane-Wells unit.

On November 19, 1964, the Road Logger was used to log the concrete pavement over Donner Summit. This highway was selected because it had not been open to traffic, and the densities of the P.C.C. pavement had already been measured.

The Road Logger completed the evaluation study on November 20, 1964. On the evaluation study the unit logged about 178 miles.

Table 1
Summary of Field Activities
Field Evaluation of Lane-Wells Road Logger

Location	Dates	Resident Engr.	Material Available: PCC	AC	CTB	AB	Subgrade	Embankment	Found.	Equipment: Break-down*	Lost Time in Hours	Mileage	Size**
Sacramento	8-26,27	F. Gau						x				1.5	M
El Dorado Hills	8-28-, 11-18	J. Hunter						x				1.4	M
Pollock Pines	8-31, 9-1, 11-18	Ed Silva		x	x	x						4.3	M
Salinas	9-2, 3	Al Jorge					x	x	x	M1,R	0	6.1	L
Cupertino	9-11, 14	B. Keller					x	x		M1, D3	0	8.4	L
San Jose	9-15	W. Smith			x					3	1	3.6	M
Dublin	9-16-18 9-21-22	S. Allen	x					x	x	T3 S, P	13	9.0	L
Tracy	9-24-25	F. Babcock					x			D3, 3	2	6.6	M
Modesto	9-28	E. Robinson	x		x							4.3	L
Mettler	9-30, 10-1	A. Zimmerman					x		x	D1, D3, M1, 1, R2	4	6.9	S
Tehachapi	10-2, 5	G. Snyder					x			D3, T2 R2, M1	8	10.5	L
Barstow	10-6, 8	B. Johnson					x		x	M1	2	12.9	L
Harritt Road	10-13	F. Kreft					x					2.7	S
El Cajon	10-14	H. Chisholm						x		M2, M3	1.5	3.6	S
Del Mar	10-15, 16, 23						x			M1, M2S	4	16.7	L
Jacumba	10-19	G. Copenhaver			x		x			D3. M2	0.5	9.7	L
Poway	10-20, 22							x		D3, M1, M2	3.5	11.9	M
San Diego	10-21	R. Pond	x	x	x					D3	0	5.9	L
Palmdale	10-27, 28	H. Meinke					x	x	x	T, D3, V2 T3	2.5	14.8	L
Calabasas	10-29	K. Mock					x	x	x	D3	0	2.6	S
Saticoy	10-30	K. Johnson					x			D3	.5	4.7	L
Pomona Fwy.	11-3	R. Duffin					x	x		V2, D3, M2	8.5	5.3	S
" "	11-4	R. Klesges						x		D3, M1	.5	5.4	M
San Gabriel Fwy.	11-5	W. Herring					x	x		D3	.5	3.9	M
" " "	11-6	C. Cano					x	x		D3, T3	1	4.8	M
Cordelia	11-13	M. Engrahm						x		1	0	0.7	
El Centro Rd.	11-16			x								5	
Donner Summit	11-19	L. Hawkes	x							R2	0	4.7	
												177.9	

*Breakdown

1= Electronic
2= Mechanical
3= Hydraulic

D = Density sensor
M = Moisture "
R = Recorder
T = Trailer

V = Vehicle
P = Power Supply
S = Misc.

**Physical size of areas available for logging purposes

L = large
M = medium
S = small (i.e., sliver)

Depth of Measurement

The depth the density sensor was measuring the soil density was determined by noting the influence a steel plate had on the nuclear readings at a given soil depth. When the steel plate no longer affected the readings this depth was taken as the depth of penetration of the radiation.

The charts of the data are shown for the two soils tested. (Fig. 1, 2) One soil was a fine sand that readily compacted to a uniform density of 108 pounds per cubic foot. The other soil was a sand and gravel that readily compacted to a density of 141 pounds per cubic foot.

A plot of the indicated nuclear density versus the soil thickness is shown in Figure 3. The data indicates that the density sensor is measuring to a depth of 5½ inches at a soil density of 141 pounds per cubic foot and to a depth of seven inches at a soil density of 108 pounds per cubic foot. This decrease in depth of measurement as the density of the soil increases is as predicted by nuclear physicists. An interesting indication from Figure 3 is that equal weight is given to the nuclear count by each inch of depth of the soil. With the portable backscatter gages the top fourth of the depth of measurement affects one-half or more of the nuclear reading. This makes the portable gages extremely sensitive to the soil density directly below the gage. With the Lane Wells Road Logger this deficiency does not appear to exist. The depth of measurement of soil density with the Road Logger is two to three times that of the portable gages using backscatter techniques.

The manufacturer states that the increased depth of measurement is due to the collimation of the source and detector. He also states that the energy discrimination of the detector and the collimation of the source and detector has decreased the effect that the top one-fourth to one-fifth of the depth of measurement has upon the nuclear readings. Our data appears to substantiate the manufacturer's observations.

The limited data that were obtained indicate that the nuclear system contained in the Road Logger is comparable in regard to depth and density uniformity to our present sand volume test.

As the moisture sensor is practically the same as used in the portable gages only limited testing of this unit was performed in the laboratory. It appears that the moisture sensor is measuring to a depth of six to eight inches, the same as the portable gages.

From these results all sand volumes were dug to a depth of six inches to insure that the same material was used for the correlation study.

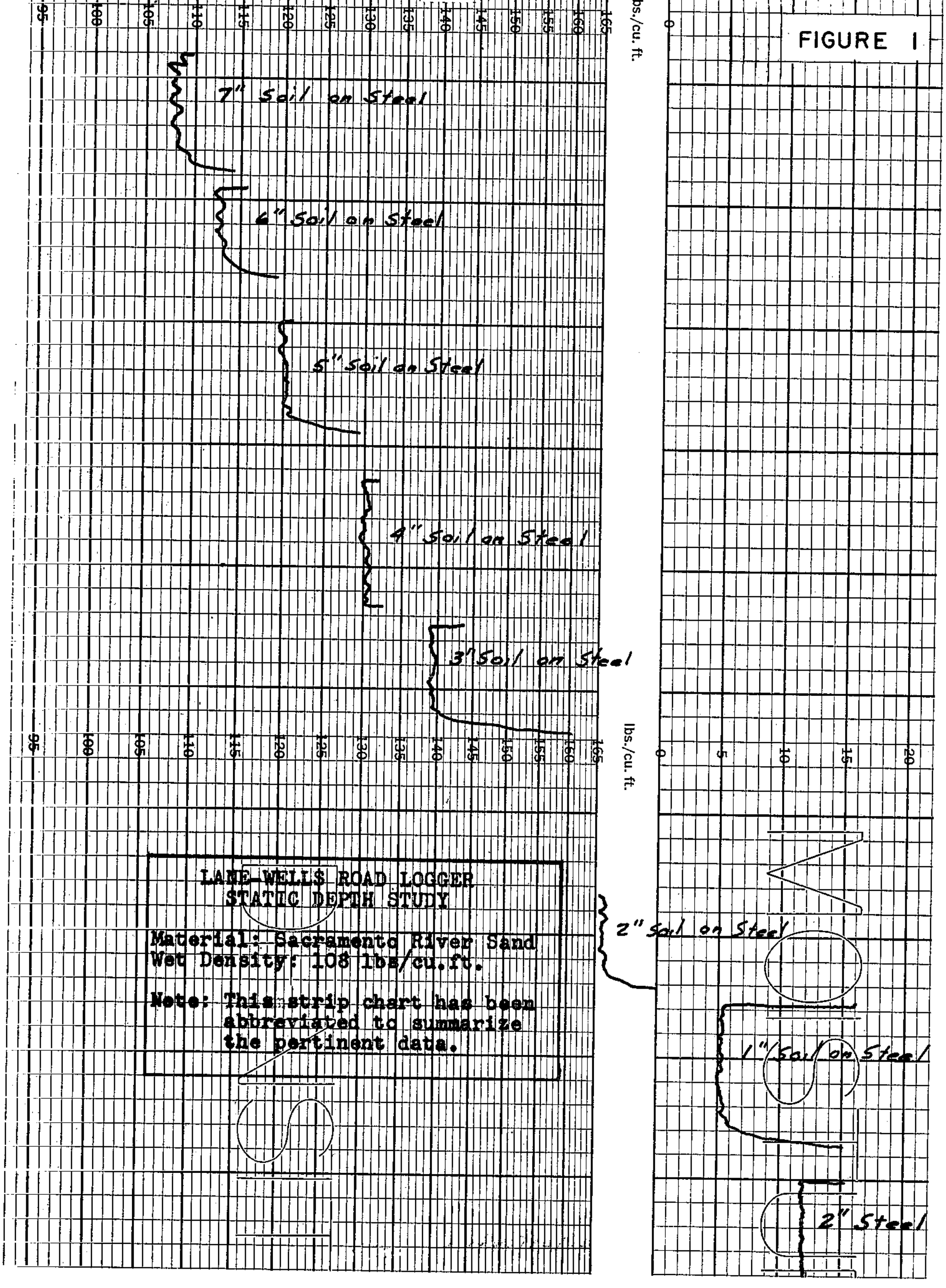


FIGURE 1
lbs./cu. ft.
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
0
5
10
15
20
7" Soil on Steel
6" Soil on Steel
5" Soil on Steel
4" Soil on Steel
3" Soil on Steel
2" Soil on Steel
1" Soil on Steel
2" Steel
LANE-WELLS ROAD LOGGER
STATIC DEPTH STUDY
Material: Sacramento River Sand
Wet Density: 108 lbs/cu.ft.
Note: This strip chart has been abbreviated to summarize the pertinent data.

FIGURE 2

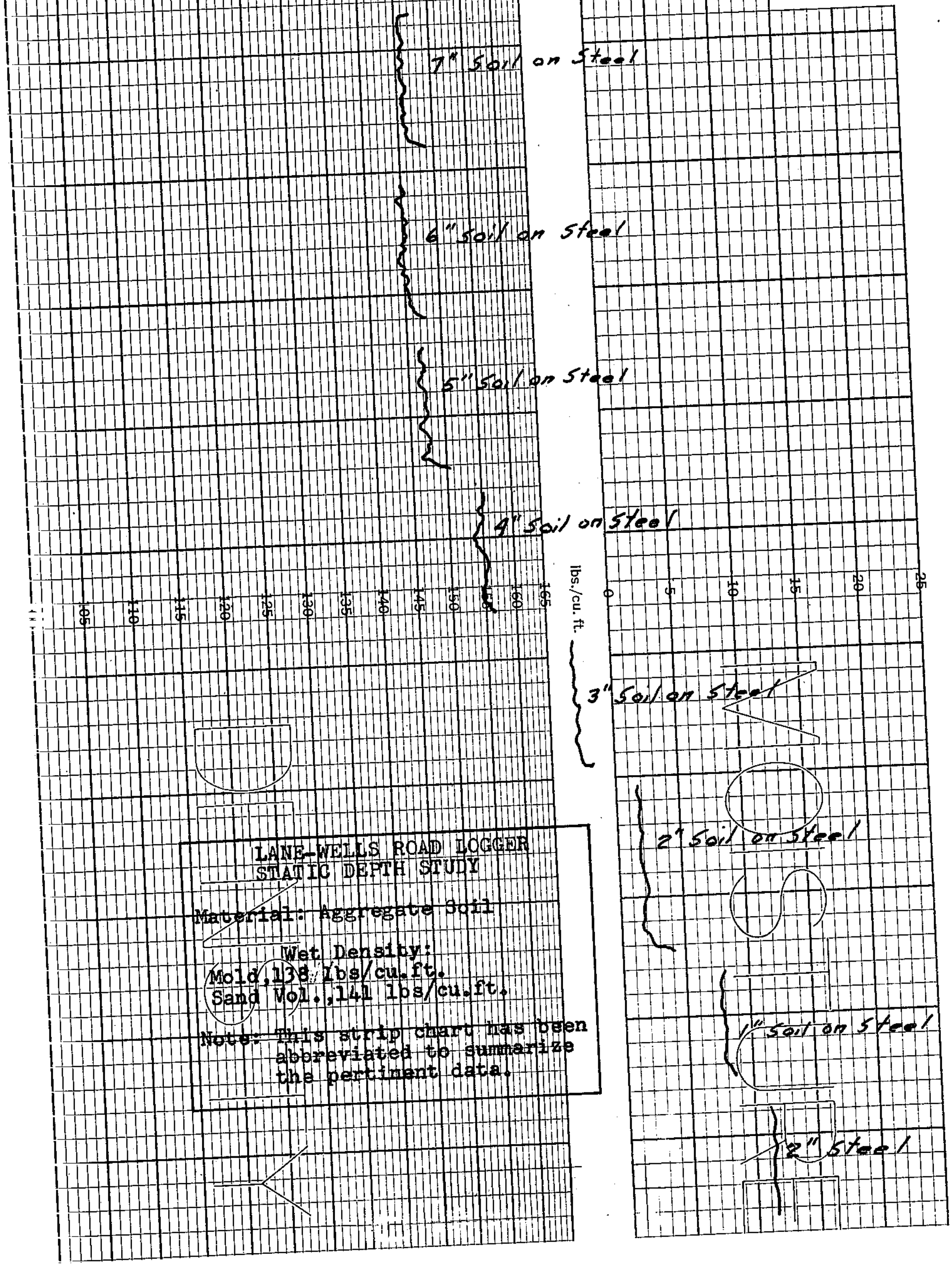
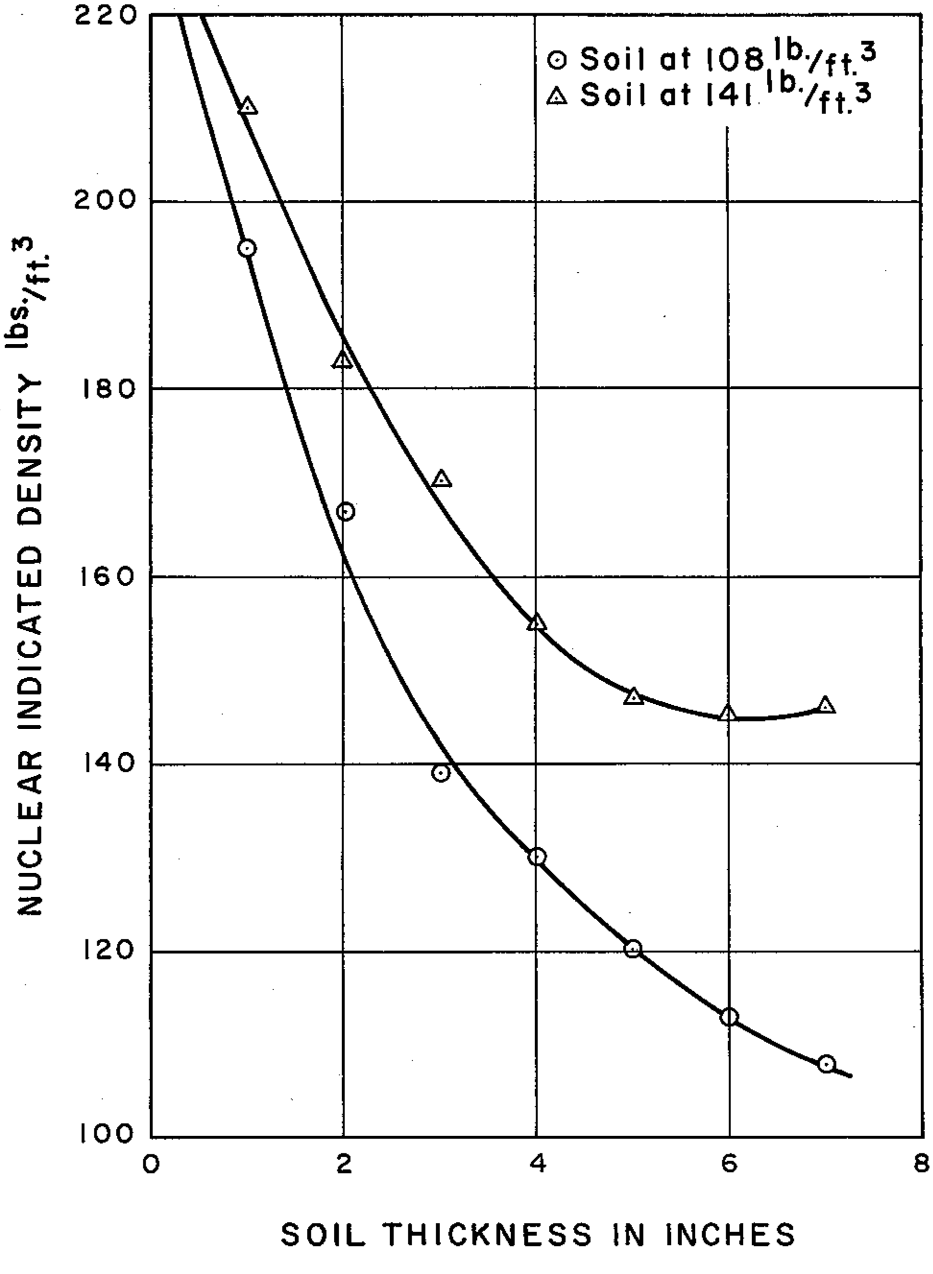

7" Soil on Steel
6" Soil on Steel
5" Soil on Steel
4" Soil on Steel
105 110 115 120 125 130 135 140 145 150 155 160 165
lbs./cu. ft.
0 5 10 15 20 25
3" Soil on Steel
2" Soil on Steel
1" Soil on Steel
2" Steel
LANE-WELLS ROAD LOGGER
STATIC DEPTH STUDY
Material: Aggregate Soil
Wet Density:
Mold,138 lbs/cu.ft.
Sand Vol.,141 lbs/cu.ft.
Note: This strip chart has been abreviated to summarize the pertinent data.

FIGURE 3

STATIC DEPTH OF MEASUREMENT
LANE-WELLS ROAD LOGGER



Surface Roughness

To evaluate the effect of surface roughness upon the nuclear readings, grooves were made on the surface of the two samples at the end of the depth of measurement studies. Due to the predominant effect of the top portion of the soil upon the readings obtained with the portable gages, this surface condition is a major item. The grooves reduced the densities indicated by the Road Logger by one pound per cubic foot. As this is probably within the accuracy of the nuclear reading it is difficult to say that grooves one-half inch deep have a measurable effect upon the Road Logger readings. This elimination of the surface condition as being a major factor in the Road Logger readings will greatly increase its reliability in the field.

Correlation of Nuclear and Conventional Tests

The nuclear tests were correlated with the sand volume wet density and oven dry moisture tests to determine the accuracy of the nuclear data. There was limited testing done with the original Road Logger received (M1065, Photo No. 2), so that insufficient data for statistical analysis are available. The new model Road Logger (M1093, Photo No. 1) was used in most of the field testing and had sufficient data for a statistical analysis. All of the correlation data presented in this report was obtained with the new model Road Logger. As the nuclear sensing heads and the electronic components are the same in both models it is felt that the same accuracy would exist with both model Road Loggers.

Two types of nuclear data were obtained: with the Road Logger moving in the normal logging operation, and with the Road Logger standing still with the sensor over a given point on the soil. These two correlations are noted as moving and static in this report.

The moving correlation was conducted at a speed of either 120 or 200 feet per minute. This resulted in a volume of soil of about 6 cubic feet being measured by the Road Logger. Generally four sand volume tests were made for each moving nuclear density with about 0.7 cubic foot volume being measured by the sand volume tests.

The static correlation was conducted with one static nuclear reading for each sand volume test. The static nuclear reading involved a soil volume of about 1.3 cubic foot and the sand volume test about 0.2 cubic foot.

With both the moving and static density correlation testing, the volumes of soil being tested by the Road Logger greatly exceeded the volume being measured by the sand volume test. This could affect the interpretation of the correlation testing. The distribution of the individual sand volume

densities from the average sand volume density, where four tests were obtained in a given area, was determined. This would give an indication of the variation in density in the soil sample being measured by the Road Logger. A plot of this distribution is shown in Figure No. 4. The data indicate that the soils tested in this study had a standard deviation of two pounds per cubic foot in the volume being measured by the Road Logger. Also that 90 percent of the densities varied up to four pounds per cubic foot. As the variation in the sand volume test method is about two pounds per cubic foot, the data indicate a significant variation in field densities.

The oven dry moisture samples are one sample combined from all the sand volume tests made in a given area. For this reason there are no comparisons of moisture variation possible within a nuclear test area.

The correlation data for the moving Road Logger readings are shown in Table No. 2. The correlation data for the static Road Logger readings are shown in Table No. 3.

The moving wet density correlation is shown on the correlation plot in Figure No. 5. With perfect correlation all points would group about a 45 degree line. The actual grouping of the points indicated that the Road Logger was reading high two to three pounds per cubic foot. The manufacturer calibrates the gage system against standard blocks and this slight shifting of the calibration curve is probably due to the use of different standards. This slight difference could be readily corrected in the standardization procedure. The standard deviation for the wet densities as directly determined is 4.4 pounds per cubic foot. Using a linear regression analysis to obtain the best line of correlation a standard deviation of 3.3 pounds per cubic foot is obtained. The distribution of the Road Logger moving densities variation from the average sand volume densities is shown in Figure No. 6. The data indicates plus grouping of the points about the sand volume average and tends to form a normal distribution curve. The data indicates that 90 percent of the tests are within five pounds deviation. As there is a possible variation of two pounds per cubic foot due to possible errors in the sand volume test, the measuring of different volumes, and variations in the density of the soil it would appear that the Road Logger is approaching the accuracy of the sand volume test. The data indicates that the Road Logger is of sufficient accuracy to be used in compaction control.

There was difficulty in obtaining the moistures on the various projects visited, as a result there is limited moisture comparisons. The moisture comparison are shown in Figure 7. The distribution of the field data is shown in Figure No. 6. The standard deviation is two pounds of water per cubic foot with 90 percent of the points within three pounds of water per cubic foot. The distribution approaches a normal distribution curve. A linear regression analysis was performed to determine the

equation of the best line of correlation. The standard deviation of this linear regression analysis was 1.8 pounds of water per cubic foot. The data indicate that the moisture determination is sufficiently accurate for use in compaction control.

The correlation data for the static Road Logger wet density tests versus the sand volume wet density tests are shown in Figure No. 8. The data from this series of tests indicate that the Road Logger was reading three to four pounds per cubic foot high. The distribution of the deviation of the static Road Logger corrected densities from the sand volume densities are shown in Figure No. 6. A normal distribution curve is indicated for the Road Logger densities corrected for the shift in the calibration curve. The standard deviation is 4.5 pounds per cubic foot with 90 percent of the tests within seven pounds per cubic foot. The correlation for the static tests is not as close as the moving tests. The reason for this is believed to be the result of comparing the moving densities of the Road Logger with the mathematical averages of the correlation sand volumes. The net result is that of comparing or correlating average values of associated data, which will agreee with less deviation than will the individual points.

The static moisture data from the Road Logger are compared to the oven dry moistures in Figure No. 7. There is some indication that the correlation line is slightly rotated, however, the data are limited and the validity of this rotation is questionable. The distribution of the deviation of the Road Logger moistures about the oven dry moistures are shown in Figure No. 6. This distribution is for the Road Logger moistures uncorrected for the slight calibration rotation. The deviation of the Road Logger moisture from the oven dry moistures form a normal distribution curve. The standard deviation for the uncorrected Road Logger moistures is 2½ pounds of water per cubic foot and corrected for the apparent calibration rotation is 2 pounds of water per cubic foot. The deviation curves and slight charge in the standard deviation indicate that the moisture calibration is reasonably accurate and the apparent error in the calibration is due to the limited amount of data available. The static moistures are within reasonable agreement with the oven dry moistures.

The Road Logger is calibrated by the manufacturer in the static condition. This is due to the difficulty in obtaining large standards that would be required to calibrate the moving condition. The moisture calibration by the manufacturer appears reasonable and adequate for use in compaction control. The density calibration for both the static and moving conditions appears to be high about two to four pounds per cubic foot. The comparison of the static and moving Road Logger densities are shown in Figure No. 9. A distribution curve is also shown in Figure 9, and it is slightly skewed indicating that the static tests indicated slightly higher density than the moving condition. The densities indicated by the Road Logger moving would

be acceptable for compaction control, however, the static densities show too large a deviation for compaction control. All moving tests were performed at a vehicle speed of 120 to 200 feet per minute so that no study of the effect of vehicle speed on correlation is possible.

TABLE 2

DATA USED FOR MOVING DENSITY AND MOISTURE CORRELATION

Id No.	Density: Average of Sand Volume	Density: Road Logger	Moisture: Oven Dry	Moisture: Road Logger
13	156	156		
14	121	130	9	10
15	124	130	9	10
16	130	137		
17			6	8
18	128	130	9	9
19	126	132	11	12
20	115	123		
21	139	144	6	7
23	135	136	8	8
24	136	138	8	8
25	133	133		
26	137	134		
27	138	138	4	3
28	138	136	4	2
29	135	131	5	3
31	134	134		
32	134	132		
33	138	139		
35	138	137	15	11
36	132	135	10	10
37	119	120	7	4
38	124	130		
39	122	125		
40	127	128	3	2
41	126	131	3	3
42	134	135	9	7
43	122	130	2	5
45	138	144	8	10
46	106	106		
47	118	127		
48	121	128	17	17
49	112	115	12	17

TABLE 3

DATA USED FOR STATIC DENSITY CORRELATION

Test No.	Sand Volume	Road Logger	Test No.	Sand Volume	Road Logger	Test No.	Sand Volume	Road Logger
13B	157	160	28A	141	139	40A	126	130
15B	130	131	B	137	139	B	128	133
16A	130	139	C	140	139	C	127	131
C	130	139	D	136	139	D	128	131
17A	116	125	29A	133	139	41A	126	130
18A	128	135	B	136	140	B	126	130
B	127	135	C	135	140	C	127	136
C	130	135	D	137	141	D	127	135
D	127	139	31A	134	131	42A	141	149
19A	123	135	B	135	130	B	132	145
C	129	131	C	134	130	C	136	147
20A	116	125	D	135	131	D	129	146
B	116	126	32A	134	134	43A	120	133
C	116	126	B	136	134	B	121	132
D	112	120	C	134	133	C	124	133
21A	140	146	D	133	134	D	123	132
C	138	146	33A	139	134	45A	138	148
23A	134	140	B	138	134	B	134	146
B	140	142	C	138	135	C	138	148
C	135	140	D	138	134	D	140	145
D	130	139	35B	141	143	46A	105	109
24A	134	140	C	137	141	B	102	103
B	135	138	D	137	139	C	111	107
C	135	141	36A	131	137	47A	118	125
D	141	144	B	129	139	C	118	127
25A	134	136	C	134	140	D	118	127
B	133	134	D	135	140	48A	123	126
C	135	136	37A	120	124	B	123	127
D	132	133	B	120	123	C	119	128
26A	134	134	C	118	123	D	120	127
B	137	135	D	117	123	49A	113	121
C	139	137	38A	125	131	B	114	117
D	139	136	B	125	128	C	112	118
27A	139	138	C	126	130	D	110	117
B	137	142	D	122	130			
C	139	142	39A	122	129			
D	137	142	B	121	128			
			C	123	129			
			D	123	127			

DATA USED FOR STATIC MOISTURE CORRELATION

Test No.	Oven Dry	Road Logger	Test No.	Oven Dry	Road Logger	Test No.	Oven Dry	Road Logger
13	11	16	23	8	9	40	3	2
14	9	11	24	8	8	41	3	2
15	9	10	27	4	3	42	9	7
16	10	12	28	4	4	43	2	6
17	6	7	29	5	4	45	8	9
18	9	10	35	15	13	48	17	17
19	11	12	36	10	11	49	12	20
21	6	6	37	7	5			

FIGURE 4

DISTRIBUTION OF DEVIATIONS OF INDIVIDUAL SAND VOLUMES FROM SITE AVERAGE OF SAND VOLUMES

NO. OF SITES: 32

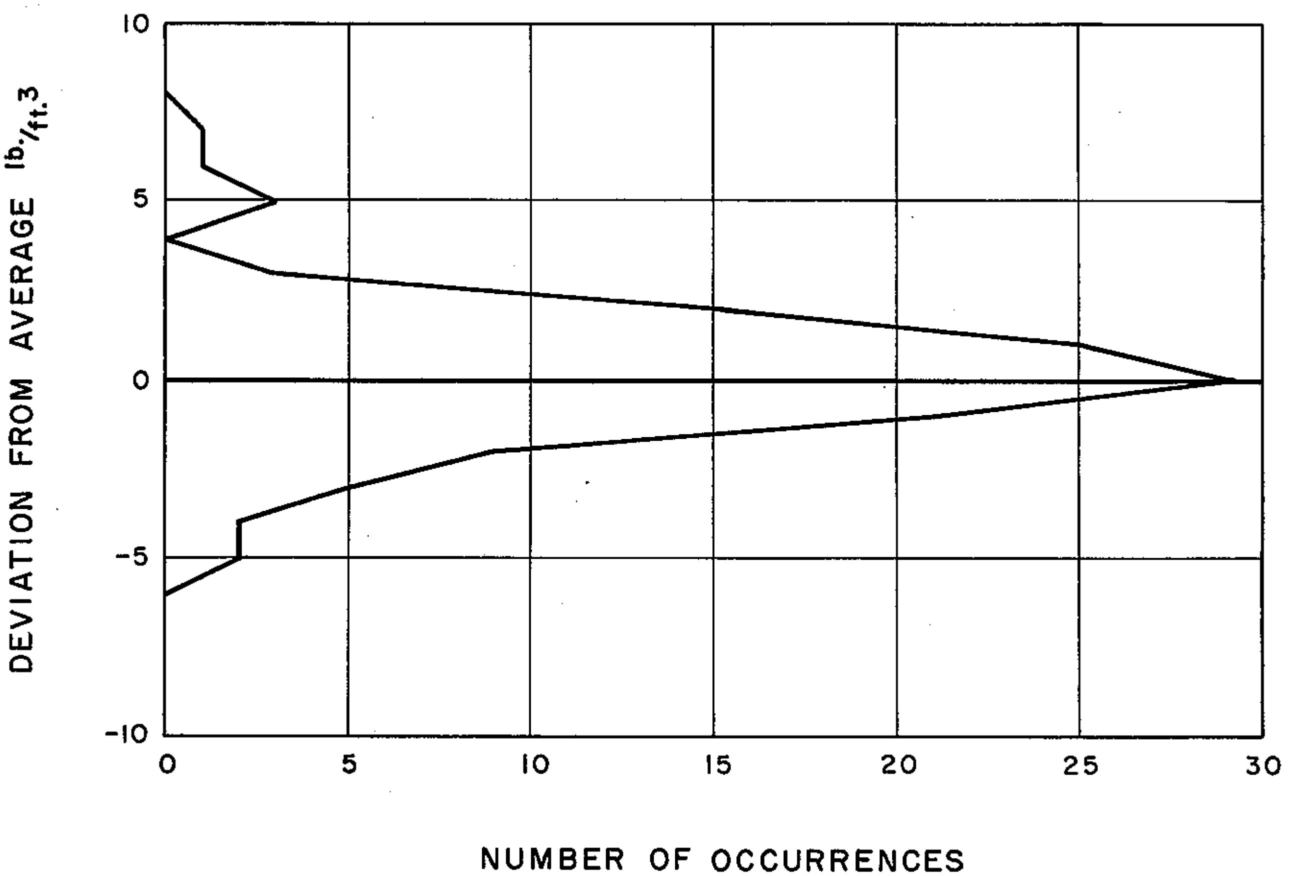


FIGURE 5

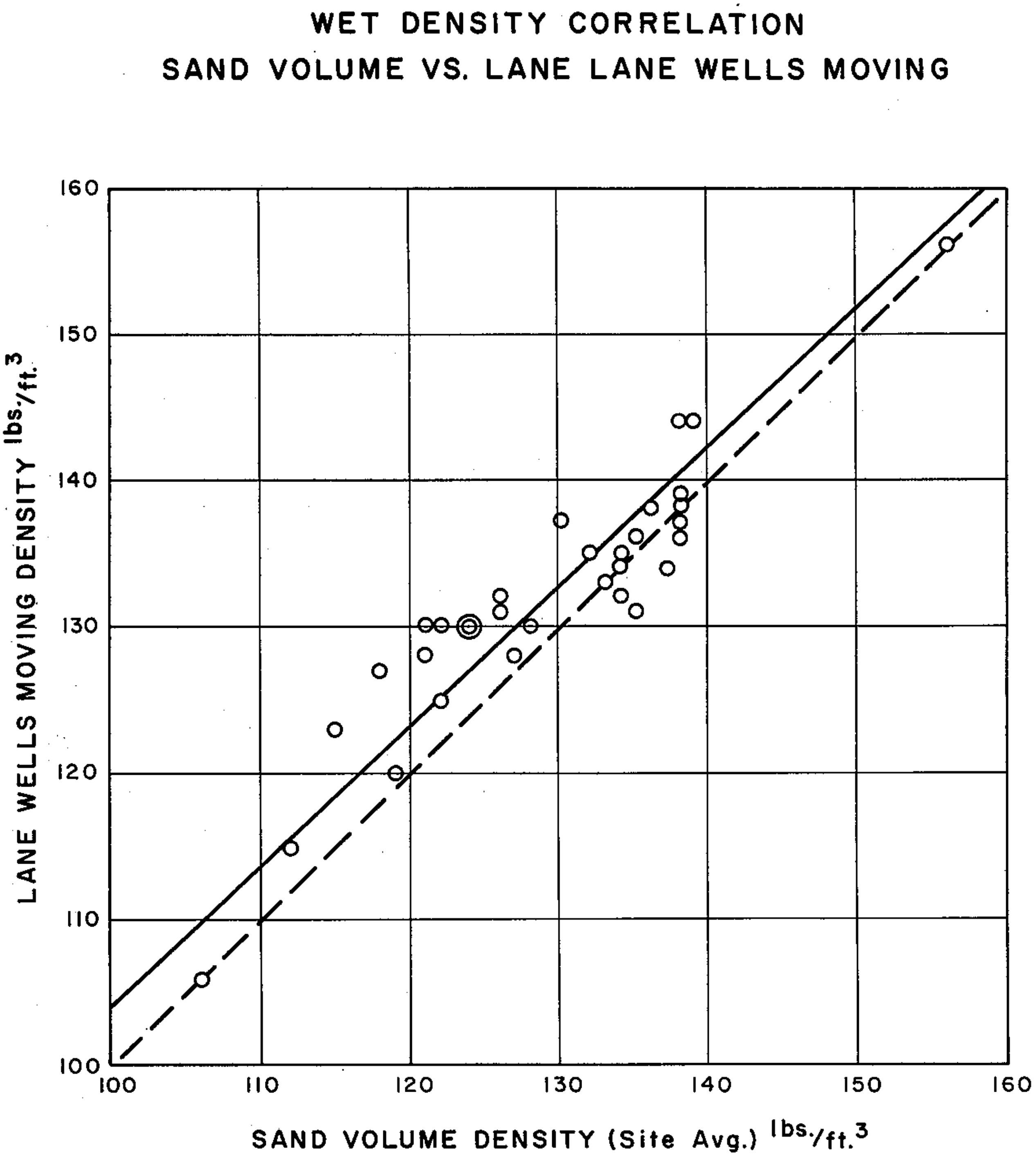

WET DENSITY CORRELATION
SAND VOLUME VS. LANE LANE WELLS MOVING
LANE WELLS MOVING DENSITY lbs./ft.3
SAND VOLUME DENSITY (Site Avg.) lbs./ft.3
100
110
120
130
140
150
160

FIGURE 6

DISTRIBUTION CURVES

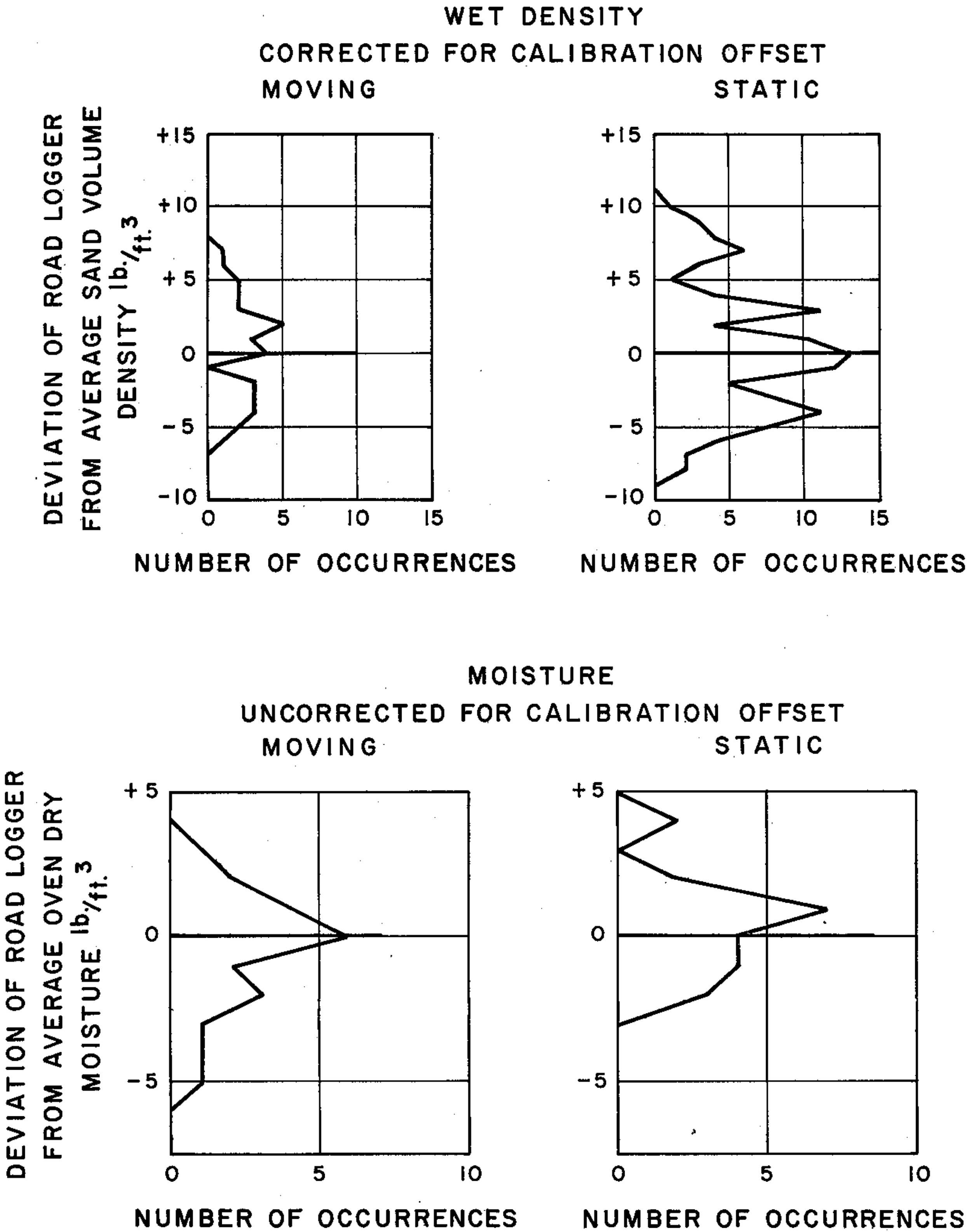
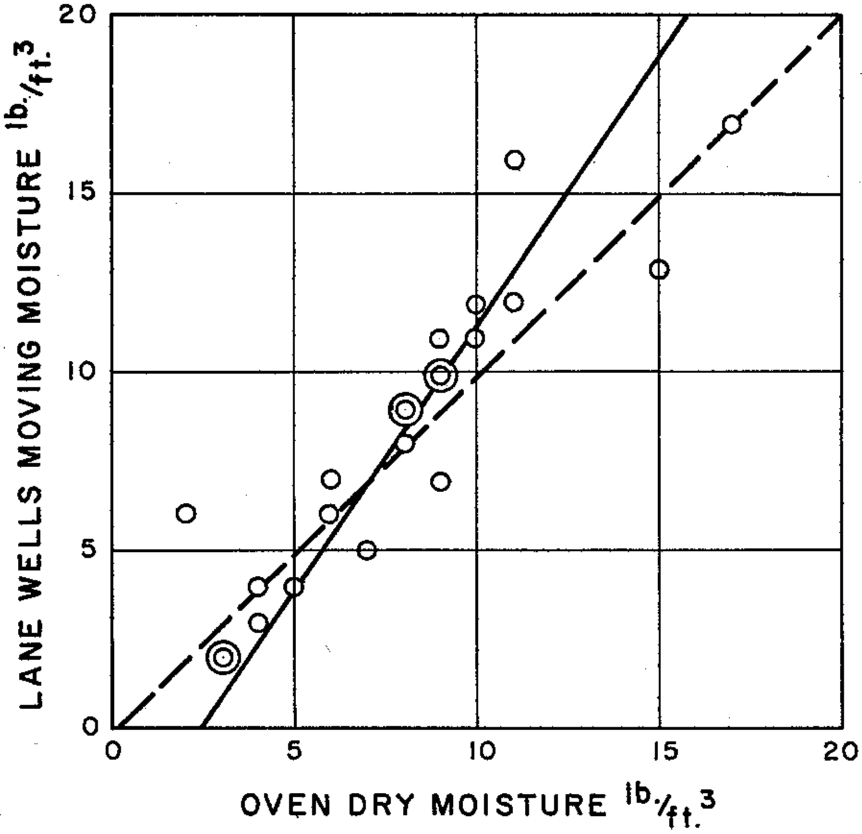


FIGURE 7

MOISTURE CORRELATION

OVEN DRY VS. LANE WELLS STATIC



OVEN DRY VS. LANE WELLS MOVING

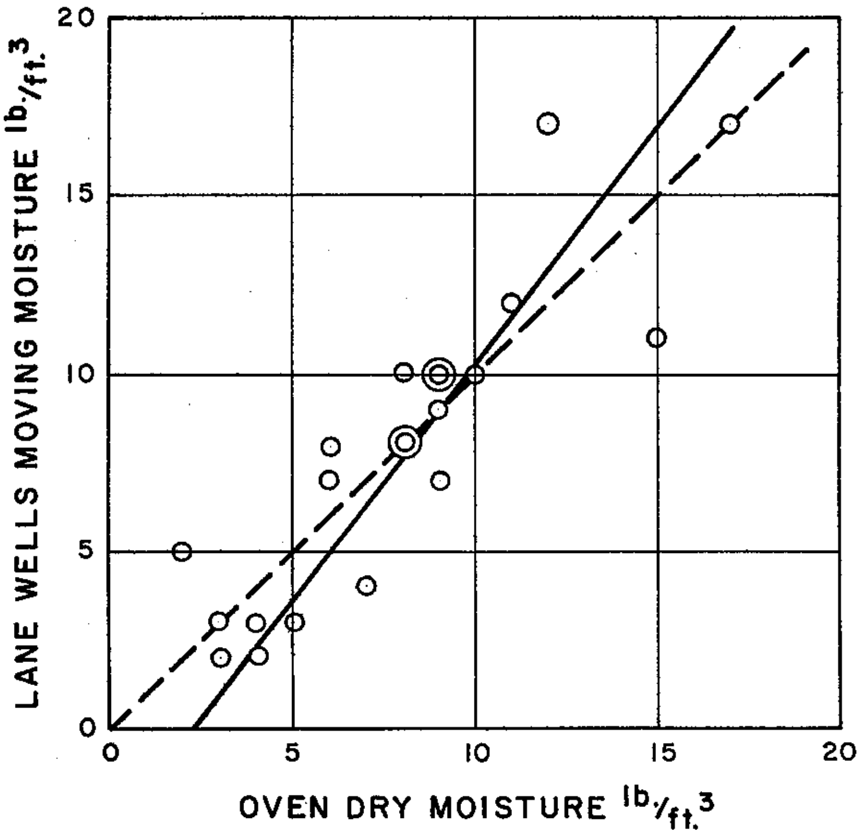


FIGURE 8

WET DENSITY CORRELATION
SAND VOLUME VS. LANE LANE WELLS STATIC

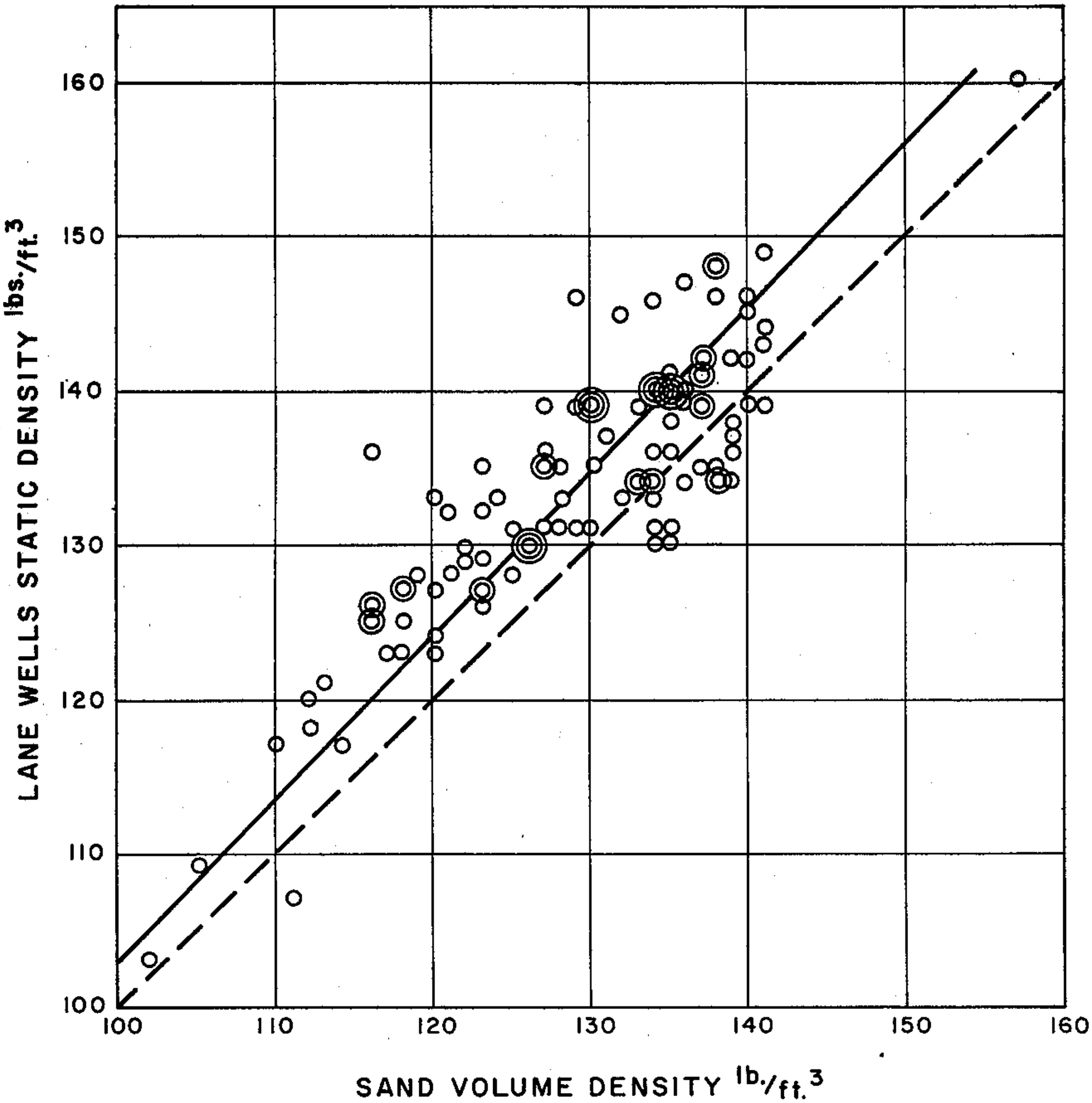
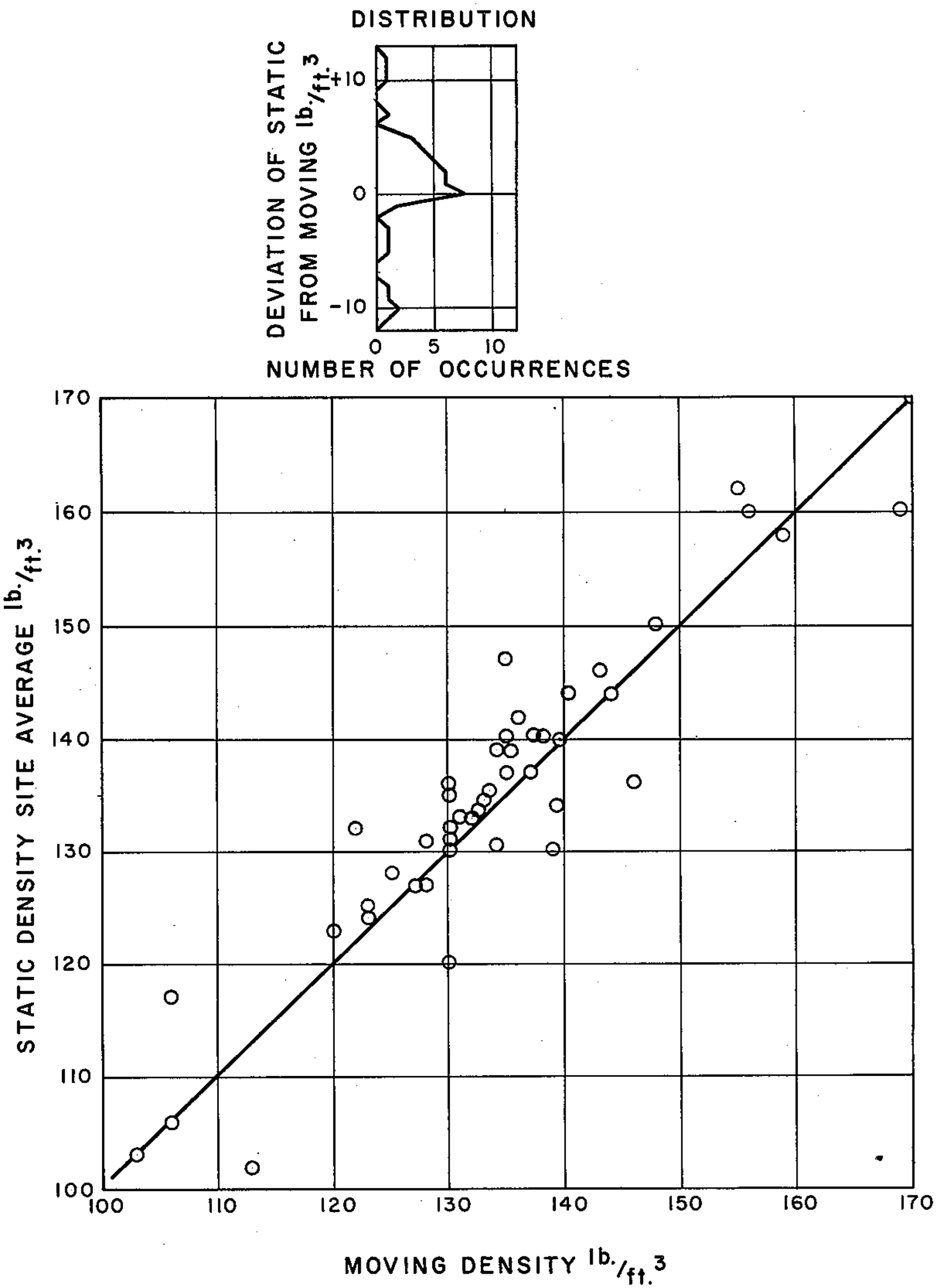


FIGURE 9

WET DENSITY CORRELATION
LANE WELLS MOVING VS. STATIC



Repeatability of Measurements

To determine the repeatability of the nuclear measurements, duplicate runs were made under the following degrees of control:

Good control - A rigid tracking arm with a flexible chain (Photo 42) follows closely (± 2 in.) upon a length of twine which is fastened to the ground.

Fair control - A rigid tracking arm with a flexible chain follows upon a course painted (lines or dots) on the ground (± 4 in.)

Poor control - Driving the Road Logger over the same general course (i.e. a bladed path) ± 10 in.

Repeat runs were made at Calabasas with ground control classified as poor. These runs as Calabasas are not illustrated. At Tehachapi four repeat runs were made with fair ground control. The first and second repeat runs are superimposed on the original run in Figure 10. The third and fourth repeat runs are compared to the original run in Figure 11.

The variation of the four repeat runs at Tehachapi from the original run are represented on Figure 12 by a frequency curve. The deviation at each station of the repeat run from the original run was used in developing this curve. The data at Tehachapi indicates that the standard deviation of repeat runs for moisture would be less than one pound of water per cubic foot and for density less than two pounds per cubic foot.

Two logging runs were made at Poway using good ground control. The repeat run was superimposed on the original run and is presented in Figure 13. The density and moisture values for both runs at forty systematically selected points were taken from this composite chart. The distribution of the variations of both moistures and densities of the repeat run from the original at these selected points are presented in Figure 14. The data indicates that the standard deviation of the repeat runs for the moisture would be less than one pound per cubic foot and for the density would be about one and one-half pounds per cubic foot.

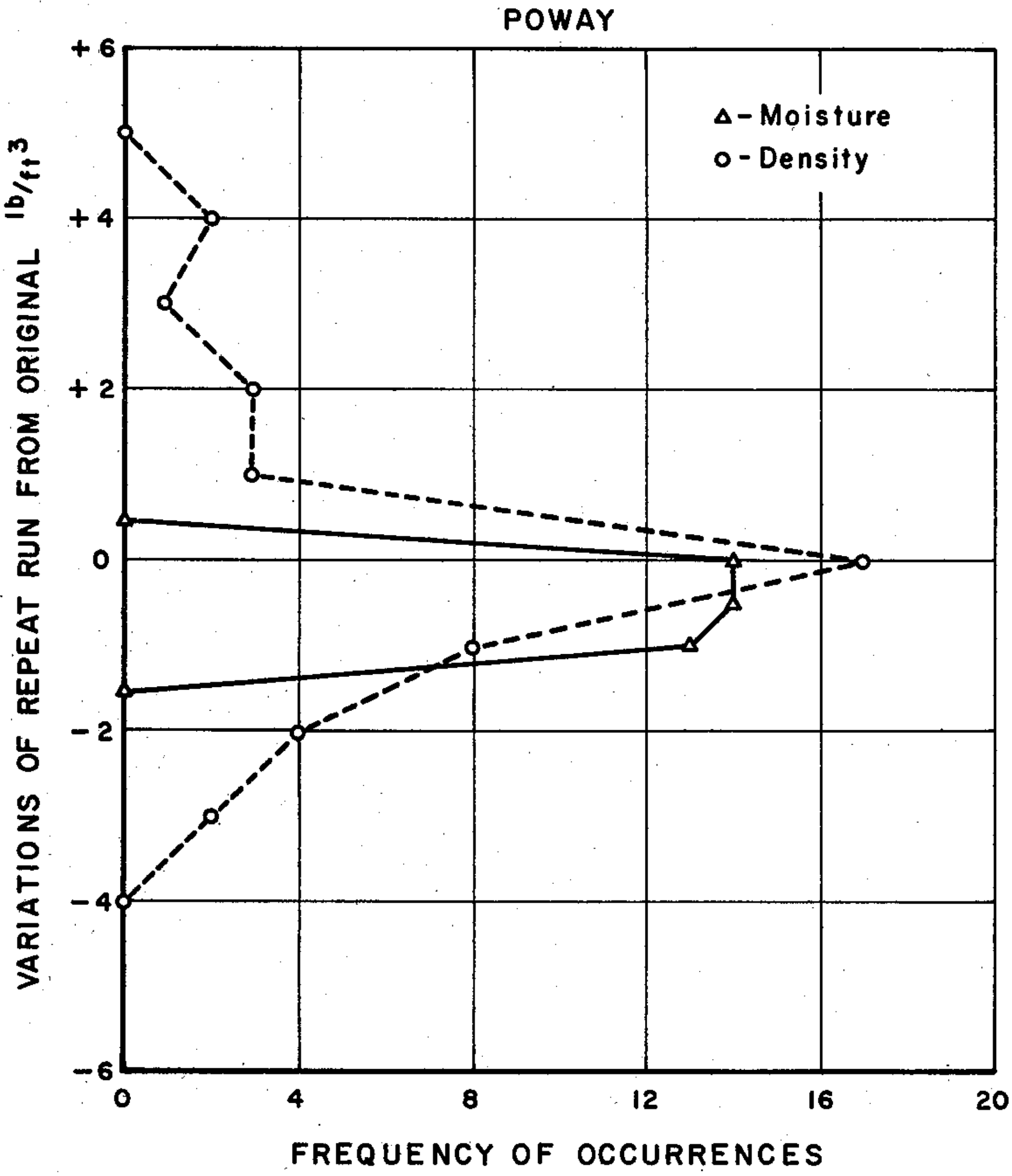
The range in density of the soil in the repeat runs was about 100 to 140 pounds per cubic foot and the range in moisture content of the soil in the repeat runs was from 0 to 18 pounds of water per cubic foot. There was no relationship between the repeat runs and the variations in the moisture content or the density of the soil.

A portion of the variation is due to not reading the same soil sample each logging run. These errors could be due to: (1) not following exactly the same path along the roadway, with an estimated error of two to four inches in a total width being logged by the sensor of about fifteen inches, and (2) not starting the run at the same station and/or setting the chart exactly for stationing. The estimated error in this item is ± two feet and would shift the horizontal scale of the chart.

Considering the potential errors in the repeat runs it would appear that the Road Logger had a repeatability of about one pound per cubic foot for both moisture and density. This would indicate that the nuclear and electronic systems used in the Road Logger are stable and would have sufficient reproducability for use in compaction control.

FIGURE 14

FREQUENCY DISTRIBUTION OF VARIATIONS OF REPEAT RUN MOISTURE AND DENSITY FROM ORIGINAL



NOTE: Effective Range of Data.
Moisture: 5 to 18 lb. per. cu. ft.
Density: 101 to 136 lb. per. cu. ft.

Effect of Variation in Air Gap

The air gap is the distance between the bottom of the nuclear sensor and the surface of the material being logged. This air gap is set at one inch at the start of each logging run. Observations indicated that this air gap below the density sensor would vary as the logging run was being conducted. It was thus desired to know what effect this variation in air gap had upon the readings obtained with the Road Logger. For these tests, static readings were used with the sensor reading the same material each time. As no difficulty had been noted with the air gap under the moisture sensor, only the density sensor was tested.

With the Lane Wells Road Logger parked at the Tracy airport on a concrete slab having a density of 146 lb. per cu. ft. the air gap between the density sensor and the surface of the slab was varied in 1/8 in. increments. The trial began with a ½ in. clearance and was progressively increased to an air gap of 1½ inches. This linear plot has a slope of 3 lb. per cu. ft. for each 1/8 in. increment of air gap. A similar air gap variation test was performed at Barstow on loose desert alluvium having a wet density of 117 lb. per cu. ft. as indicated by the nuclear measurement. The slope of this curve is 2 lb. per cu. ft. for each 1/8 in. change in air gap. The resulting graphs of indicated wet density versus change in air gap are presented in Figure 15.

Being aware of the effect of change in air gap adjustment on static density readings: when logging on rock embankments, critical attention was paid to the effect of the unavoidable variation in air gap caused by the rough surface. When the loss of air gap adjustment was only momentary, as when deflecting or riding over a rock or other obstruction, the net effect on the density reading was slight.

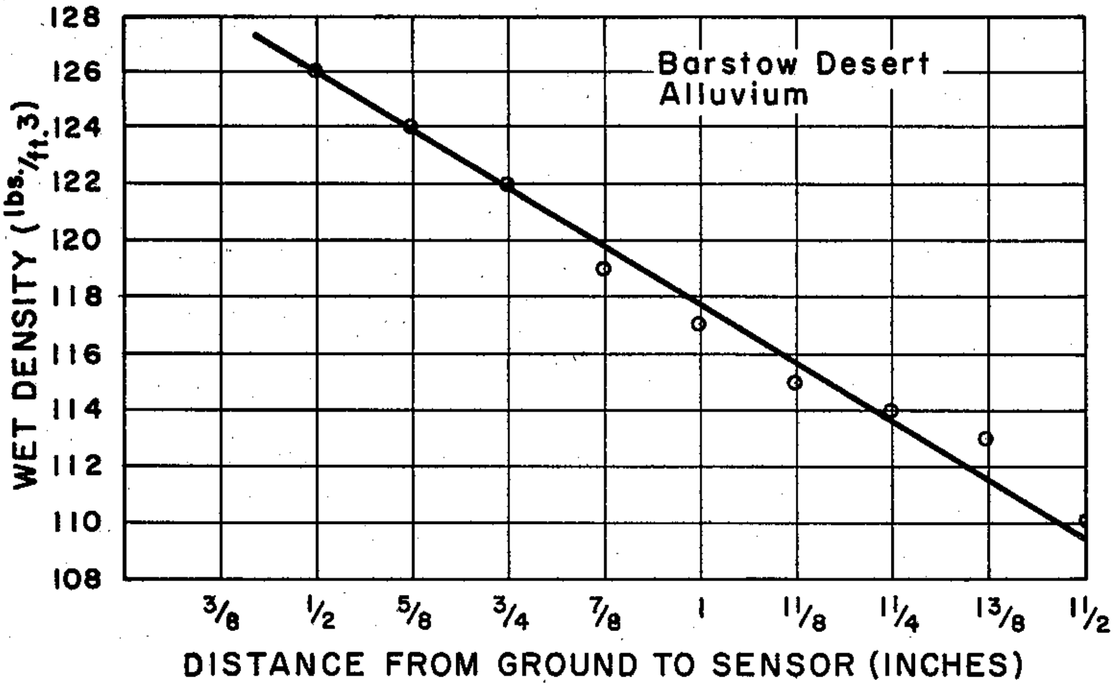
However, when the sensor catches and pushes a rock along producing a trough beneath the unit, or raising the sensor so as to increase the air gap there is a pronounced effect on the density reading. Photos 31 and 32 taken at Poway illustrate this trough production. The Poway strip chart, Figure 16, shows the lower indicated density resulting from the greater total air gap caused by a rock.

From time to time the Road Logger was stopped and a measurement of the air gap taken. Sixty-three percent of these measurements were very close to the desired 1 in. value, while 26 percent were near 1-1/8 inch. Eleven percent of the measurements were nearer 1¼ inch. Since normal ground unevenness would produce a random variation in air gap, the "plus bias" of the measured air gaps indicates that the sensors weight is inconsistently supported. This could be the consequence of a variation in spring stiffness or hydraulic suspension caused by the movement of the unit in logging. Photo 12, shows the type of suspension used on the sensors.

A loose soil can also cause a decrease in air gap, but the operator can detect this by periodically checking the depth of the density sensor's wheel tracks. If the depth of track differs from that when the air gap was last set - the air gap must be readjusted for the new soil condition. The manufacturer has suggested that this could be corrected by the installation of an automatic air gap adjusting device.

FIGURE 15

DENSITY SENSOR AIR GAP
LANE WELLS ROAD LOGGER (M 1093)



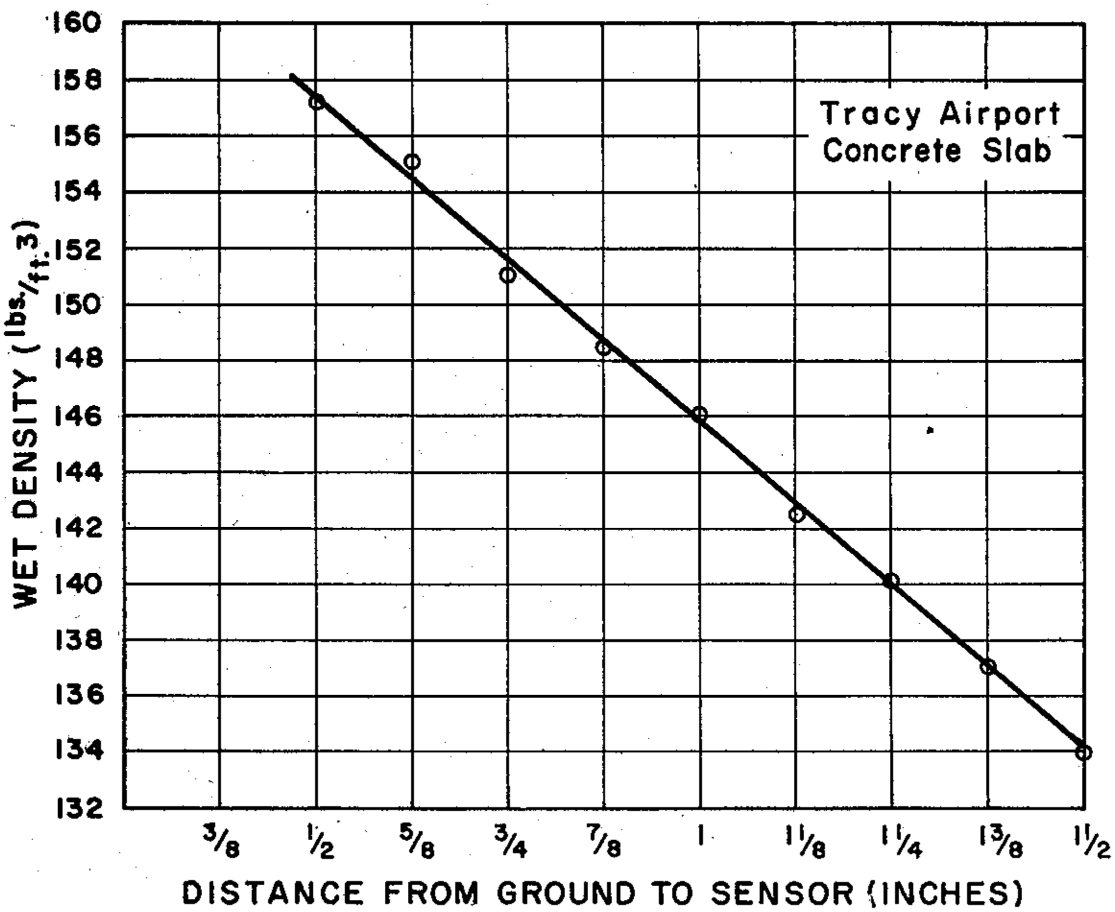
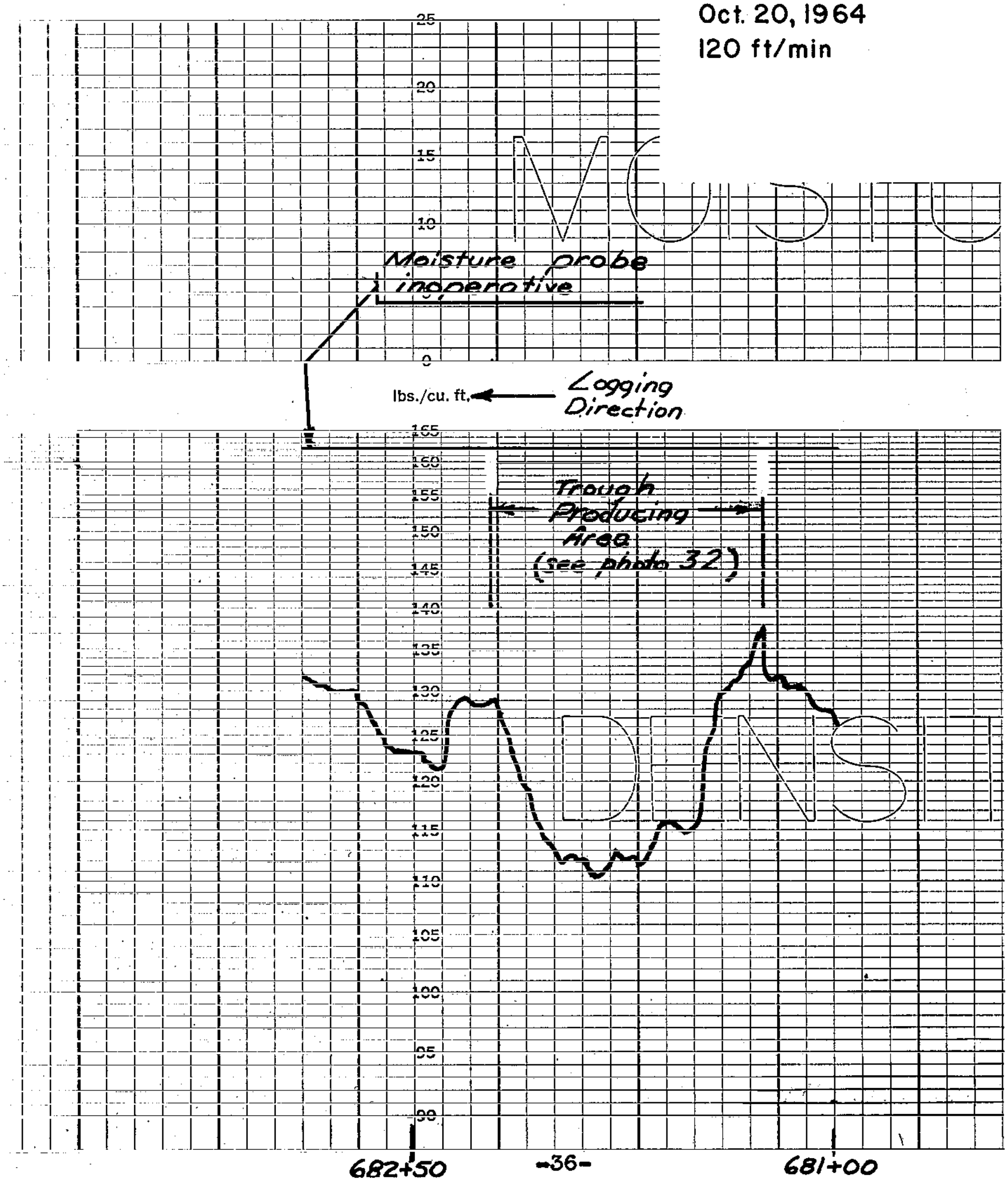


FIGURE 16

TROUGHING EFFECT

Poway
Oct. 20, 1964
120 ft/min



Surface Texture of Soil

It is apparent that any soil surface condition that restricts the proper functioning of the moisture or density sensor would limit the use of the Road Logger. Such a condition is surface texture.

The Oklahoma Division of Highways had used the Road Logger only on bases and subgrade in their original work. This was because they felt the embankment material too rough for the sensors to function properly. We have been recently informed that they are now using the Road Logger to a limited extent in embankment compaction control. During the evaluation program an extensive study was made of this surface roughness aspect.

From the experience gained on the field evaluation, it is estimated that the Road Logger can operate on embankment areas 90 percent of the time on surfaces compacted with: rubber tired rollers, stiff leg rollers, or segmented rollers. The nuclear unit is effective 50 percent of the time on haul roads. The difficulty arises when a sheepsfoot roller is used. This surface, "as is" can be logged less than ten percent of the time.

The nature of the sheepsfoot roller leaves about three inches of uncompacted soil on the surface. This loose material must be removed in order to log the underlying compacted soil. This can be done easily by a blade.

Under certain conditions a blade creates a problem. If the material being placed is a heavy clay or is rocky, the blade can tear the surface or drag a rock. These actions actually make the surface worse than before. This situation was noted at Calabasas and is shown in Figure 17.

When logging an area that has surface roughness due to tearing it has been noted that the indicated density drops, presumably due to the looseness of the material caused by the tearing.

When a rock has been dragged it creates a small ditch or trough. As the sensor passes over this trough a loss of proper air gap occurs and the indicated density is low.

In this study it was found that when the first pass was made with the blade causing tearing or troughing, then a second pass with the blade would average the material by filling the torn or troughed area. This was visually evident in the field.

Therefore, it is felt that by blading a rough surfaced embankment once or twice, whichever is necessary, the Road Logger can be effectively used on these rough embankments 70 percent of the time. On surfaces that are compacted with segmented, or rubber tired rollers blading of the surface would be seldom required. It thus appears that the effects of surface texture may be less of a problem in the field use of the Road Logger for compaction control than had been anticipated.

Logging Speed

The Road Logger is designed to operate at speeds of 50 to 200 feet per minute while logging. The speed of logging, combined with the time constant, will determine the volume of soil being measured. A chart has been prepared showing the volume of soil being measured at various speeds for a time constant of three seconds. See Figure No. 19. The manufacturer recommends a logging speed of 120 to 200 feet per minute. In this range of speed the volume of soil being averaged is about four to six cubic feet.

The miles of compacted material that can be logged in a day is also related to the logging speed. For practical purposes the maximum speed should be used. The only occasions where the recommended range of speed, 120 to 200 feet per minute, was found to be disadvantageous was on extremely rocky embankment. On rocky embankment it is necessary to reduce the speed to 50 feet per minute to reduce vibration and increase the time constant to five seconds to obtain a larger volume of soil for measurement.

At several locations during this evaluation study duplicate runs were made at different speeds. The charts for three of these locations as presented in Figures Nos. 20, 21 and 22.

At Calabasas two duplicate runs were conducted at speeds of 50 to 200 feet per minute. For the 50 feet per minute logging speed a length of roadbed about two and one-half feet was averaged for a volume of about one and one-half cubic feet. The chart produced is very erratic with many sharp hills and valleys indicating large variation in point to point moisture and density. At a vehicle speed of 200 feet per minute a length of roadbed of ten feet was averaged for a volume of soil of about six cubic feet. The chart produced is much smoother than for the 50 feet per minute, and the low density areas are still well defined. From the chart it appears that the duplicate runs are offset about ten feet horizontally and in general the density logged at 200 feet per minute follows the low portion of the 50 feet per minute density. The moisture logged at 200 feet per minute closely follows the average moisture indicated by the slower logging speed. There is sufficient resolution at the 200 feet per minute speed to define areas of low compaction.

At Poway four duplicate runs were conducted at four different speeds. The speeds used were 40, 75, 120, and 200 feet per minute. The average densities indicated by the four different vehicle speeds are about the same. At 40 feet per minute four locations with lengths less than ten feet (generally about five feet in length) were recorded where low densities existed. As the vehicle speed was increased these short areas of low indicated density diminished, and on the 200 feet per minute logging chart these low density areas have disappeared. Realizing the increase in soil volume being measured by the increased speed this averaging out of the densities is what was expected. The same trend occurred in localized areas of high

density. In areas where low or high densities existed for a distance greater than ten feet these areas were still recorded at the higher vehicle speed. The moisture charts indicate about the same moisture at all of the speeds used. This would indicate that there were no localized high or low moisture spots at Poway. The data indicated that sufficient resolution is obtained at 120 to 200 feet per minute speed to define areas of low density.

At Del Mar duplicate runs were made at three vehicle speeds, 40, 120, and 200 feet per minute. The average moisture and density for all three runs was about the same value. The run at a vehicle speed of 40 feet per minute showed many hills and valleys, indicating localized points of variable moisture and density. The runs at 120 and 200 feet per minute had traces that were much less erratic than that of 40 feet per minute. The areas of higher or lower density and moisture were well defined.

The data presented, and other variable vehicle speed data obtained, indicate that sufficient resolution is obtained with the Road Logger to define areas in excess of ten feet in length of high or low moisture and density at vehicle velocities of 120 to 200 feet per minute. This substantiates the manufacturer's recommendations. When operating on rocky fills (about 50 percent plus three inch rock) slower speeds are required to reduce virbration of the equipment. Increasing the time constant will enable the obtaining of usable charts.

An important item is the distance traveled, at different speeds, for the Road Logger to respond to moisture and density changes. This was determined at Barstow and Del Mar by driving from fill to concrete bridge and back to fill again. The chart obtained at Del Mar is shown in Figure No. 22. The change in density was from soil at 125-130 to concrete at 160-165 pounds per cubic foot. The tracing at 40 feet per minute required nine to ten feet to record this change; at 120 feet per minute required 16 to 18 feet to record this change; and at 200 feet per minute required 23 to 25 feet to record this change in density. This increase in distance required to note the change in density with increased speed was expected. This data indicates that about twenty feet of higher or lower density material is required before the Road Logger will note the correct density at speeds of 120 to 200 feet per minute. For example, if a low density area exists for about ten feet of the chart the true minimum density will not be recorded at speeds of 120 to 200 feet per minute, but a valley in the chart will be formed. For compaction control it is felt that this is not a serious deficiency in the Road Logger because it is felt that these small areas of low density are not as important as the overall trend of the density.

A similar condition exists with the moisture changes. The time lag of response for the moisture is about the same as with the density chart.

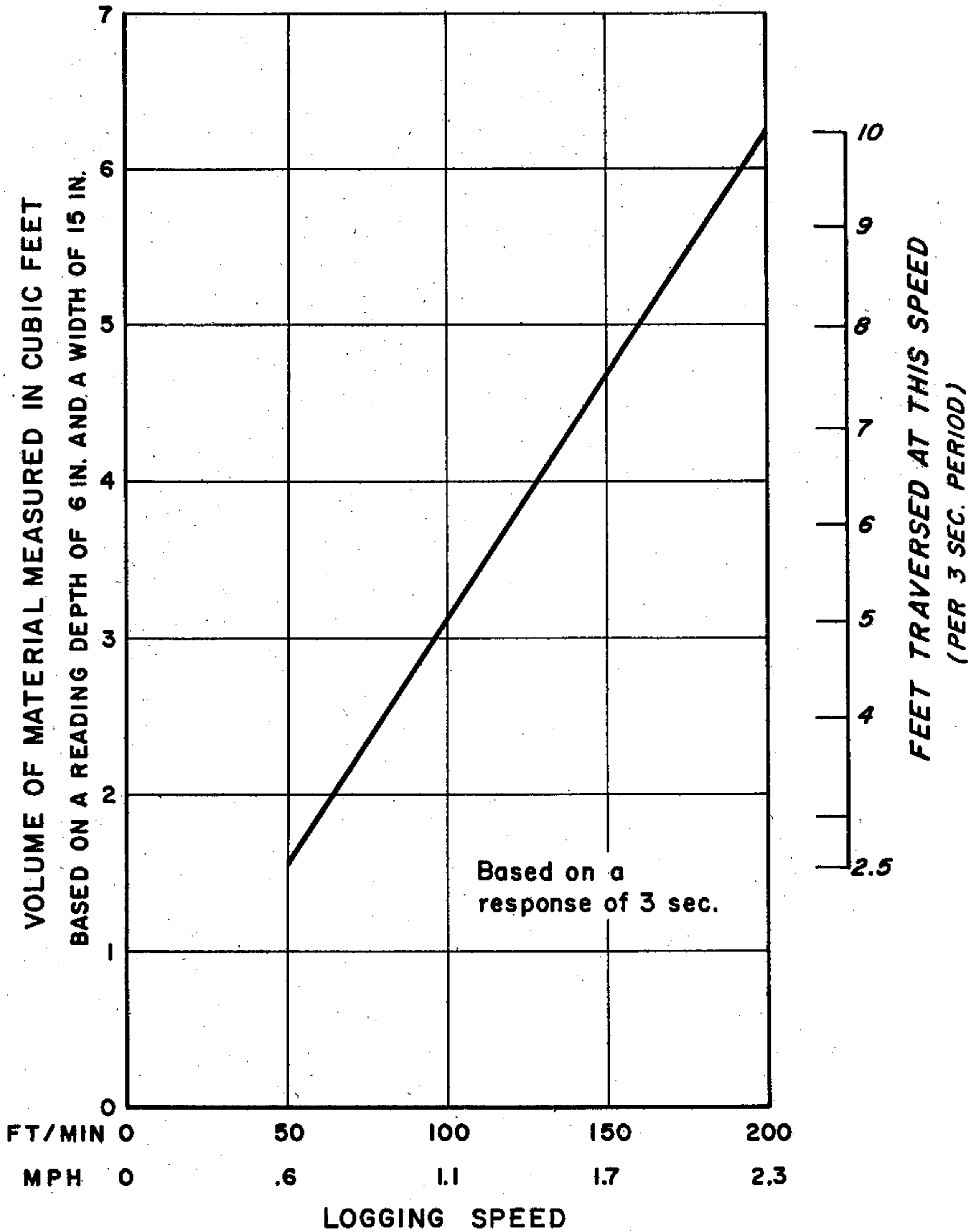
This time lag in response appears to be about two and one-half times the distances averaged for the moisture and density determination. Reduction of this time lag would result in increasing the erraticness of the charts obtained. It appears that the recommendations of the manufacturer as to vehicle speed and time constant is a valid compromise for these two inter-related items. With the variable maximum density of most embankment soils it is seriously questioned if the absolute value of the high or low density areas is important. The extent of the area can be defined with sufficient accuracy, and it is felt that this is the important item of concern in compaction control. When reduced time lag is required at 120 to 200 feet per minute vehicle speed it can be obtained by reducing the time constant to one second.

As previously discussed, there is no reason why the moving and static moisture or density readings should correspond. They are not only reading different volumes of soil but the time lag of the moving determinations will prevent a true determination of the soil moisture and density at a given point. The data from Figure No. 9 indicates a standard deviation between the moving and static readings of about three and one-half pounds per cubic foot. This would indicate that a three to four pounds per cubic foot density variation could occur at a localized point and not be recorded on the moving chart. The studies conducted of various speeds of vehicle and of the time response of the electric system indicate that this is a reasonable value. As the average fill density is of most concern in compaction control it is felt that this masking out of the localized density variation is a desirable feature of the Road Logger.

LANE-WELLS ROAD LOGGER EVALUATION

Volumes measured by Road Logger

At Various Logging Speeds in Measuring Average Density



[illegible]

Economic Evaluation

When using the Road Logger as a compaction control device on several projects in the same general area, it appears that about 100 miles of logging could be performed per month. This would involve a cost of $3,500 to $4,000 for the fixed fee and mileage cost of the Road Logger per month. The cost of an operator would be about $1,000 per month for a total cost of operation of $4,500 to $5,000 per month.

The cost of the present compaction control is principally the cost of the men required. It is estimated that the average cost per month for a man and vehicle is in the neighborhood of $1,000. This would indicate that about four to five men would need to be replaced to economically justify the use of the Road Logger. It is doubtful that the Road Logger would replace this number of men.

The number of man months assigned to compaction control per project depends upon several items, such as: volume of embankment placed, time per sand volume test, difficulty of compaction, number of tests, and related items. The men are seldom assigned full time to conducting field density tests, which makes an estimated cost of our present testing difficult. However, several generalized statements can be made. The Road Logger would have greatest economic justification under the following conditions: (1) several simultaneous projects within a radius of 50 miles, (2) large volume of earth work being placed rapidly, (3) three or more normal high speed contractor operations.

There are several intangible items in the use of the Road Logger that would be difficult to assign a fixed value to. The obtaining of a large amount of data instead of spot tests is of some value. This could lead to more uniformly compacted embankments or structural sections, thus improving the completed project. The measuring of large volumes of soil with the Road Logger instead of the small volumes with the sand volume equipment would tend to record average densities instead of extremes. This may or may not be desirable, but these larger volumes can be sampled much faster and the strip chart is a permanent record of the roadbed. Considering these intangible items it is felt that the concurrent use of the Road Logger on two large or three medium size projects would justify its cost.

The only method of obtaining a usable economic comparison between the present method of determining the field density and the use of the Road Logger would be to specify that the Road Logger be used for determining the field densities on several projects. Then, by estimating what conventional testing would have cost, a reasonable cost comparison could be made.

Interpretation of the Road Logger Data, Use of the Road Logger in Compaction Control

Compaction control of soil in the field is presently done on the basis of density. The established procedure is to compare field density as determined by the sand volume apparatus with a maximum impact density determined for soil from the same test site. The impact portion of the control testing is laborious, and is frequently performed for each field density taken. Thus, the scope of the control testing is limited in part by the required impact testing.

It is possible but not practical to attempt to directly replace the sand volume test with the Road Logger. It is technically feasible to evaluate a density point on the strip chart by comparison with impact test data representing that point. The comparison, however, would not allow a judgment of the other chart densities, except for that particular point. If it is attempted to establish a control for any length of chart using a single maximum impact test with the minimum relative compaction concept, the net effect is to raise the average degree of compaction required above that indicated by the present testing procedure.

To use the Road Logger for the control of compaction, a practical method is required that will allow a simple evaluation of the entire strip chart. The process should allow immediate acceptance or rejection of all or portions of the roadway.

One possible method is presented in the following pages, however, there are other methods of utilizing the type of data obtained with the Road Logger. Its development and explanation is offered in the following paragraphs, together with examples of its application.

It may be demonstrated that the Road Logger will duplicate the range and distribution of field densities as indicated by the sand volume testing of a length of roadway of similar material. The density data for the two methodsof density testing are plotted in the form of ogive curves, or cumulative percent versus density. This data is presented for four locations that were tested with the Road Logger during the evaluation program, Tehachapi, San Elijo, Barstow, Salinas, Figures Nos. 23, 24, 25, 26. It is clear that the overall picture of field densities is the same whether established by a relatively few points as by the sand volume test, or by an infinite number as presented by the Road Logger. There is a slight offset between the curves for the two methods of measuring field densities due to the calibration error which was discussed previously in this report.

The plot for Salinas is included, although the portion evaluated shows a greater percentage of low density material logged than that represented by the sand volume data. However, it is desired to use this material to illustrate the control concept.

The maximum impact test data as obtained in conjunction with the sand volume control tests is presented in the same form. These follow the same pattern at a higher density. It was believed that further study of the general relationship of the range and distribution of field and laboratory densities might be profitable.

Actual compaction control data was obtained for some 15 jobs. These are considered representative of those which might be encountered in actual practice; some had considerable difficulty with compaction, and some had all of the tests passing the required compaction standard.

A general characteristic of these data is that the range of field densities is greater than the range of associated test maximum densities, which is to be expected. The ratio of the range of field densities to that of the impact test is from 0.8 to 3, with the average about 2.

The second feature of the data is that there is always a field density below which all tests fail. Above this value there is a limited range of field densities which may pass or fail depending on the associated impact test. At the bottom of this gray zone are those field densities that are marginal. For example, on a particular job all field densities of 124 lbs per cu ft fail. If there should be eight tests at 125 lbs per cu ft and six of them fail, probably the other two should also fail. Perhaps at 126 lbs per cu ft half fail and half pass. As the field densities go up they rapidly shift to the point where all tests pass. This suggests that there may be a rational method of controlling field densities based on a minimum permissible density.

A third observation, and a useful one, is that the distribution of densities obtained in the field or laboratory from a reasonably similar material is essentially a normal distribution. If the cumulative percent versus density is plotted on probability paper, the plot is very nearly a straight line except for the portion above approximately the highest ten percent. See Figures 27, 28, 29, 30. A reasonable deduction is that much of what in the past has been regarded as varying material causing a variation of field densities is actually a normal variation of densities within a similar material.

This suggested test method is based on the following: that a contractor cannot compact an area of reasonably similar material so that the lowest density will pass the required density control, without having all densities pass its required

[illegible]

compaction standard. Therefore, a simple and straightforward method exists for field density control. The concept is based on specifying a minimum density control for passing or failing areas of compaction. It is especially applicable to the Road Logger, but would have similar advantages if used with the more conventional field test methods.

The soil in an area to be controlled must be identified so that the appropriate control can be applied to it. This identification is based on the practical ability of the inspection personnel to distinguish the materials used on the job. Generally there is little confusion on a project as to whether a soil is "rocky-clay" or "cobbles" or "sandy-silt" or "tuff."

The range of impact maximum densities for a particular material must be established prior to field testing. The material used in the impact tests must reasonably represent the variations within the material. Probably ten curves are sufficient for any material. In very uniform material a satisfactory initial value can be established with fewer tests.

The maximum impact test densities are plotted on probability paper in cumulative percent against wet density. The data should plot as essentially a straight line up to about 90 percent. There should not be more than 2 lbs per cu ft variation from the best straight line. A definite break in the line indicates that the data is from two distinct materials. In this event two curves are plotted from the data, and two controls established. As additional impact tests are made the cumulative percents are recomputed and the line replotted. If a change in material is suspected, and the number of tests is such that the latest tests do not significantly affect the plotting, only the most recent tests need be used in the computations. Generally, minor variations in the best straight line do not significantly affect the control value established.

The lower 10 percent cumulative maximum impact density value is used as the lower control value. This density is that value at which 10 percent of the range of impact maximum densities are lower than, and 90 percent are higher than. This density is multiplied by the specified relative compaction factor, either 90 or 95 percent. The value computed is the minimum filled density permitted, and is used as a primary control of compaction.

The values offered in this example are intended to illustrate the concept, and are not arbitrary. Further study of more extensive data might indicate that other limiting values may be desirable. It may be that this should be a decision made for a particular material.

It is realized that the concept is based on a study of field density distributions obtained under our present control methods. It could be possible for a contractor working with a mixed soil of high and low density material, and controlled only on the

basis of a minimum permissible density, to concentrate his efforts on the light weight portion of the mixed material. The result would be that the remaining material of higher density would not be properly compacted, though passing the minimum control established for the general material type. Therefore, provision should be included that would enable the inspection forces to achieve the desired degree of compaction of all portions of the mixed material. It could be simply specified that substantially all of the distribution of achieved field densities be within the 90 or 95 percent envelope of the distribution of test maximum impact densities. The envelope of the cumulative relative compaction distribution is shown by the dashed line on Figures 23, 24, 25, 26. It is required that the sampling for the impact testing be representative of the mixed material.

Compliance with this requirement could generally be determined by inspection, especially with uniform material having a small range of maximum impact densities. In mixed material having a considerable spread in control density distribution, particularly where inadequate compaction of high density material is suspected, this provision could be applied. The computations required are simple and can be performed in the field.

Obviously minor or inconsequential deviations below the minimum control density, such as might be caused by bouncing on a very rough surface, or catching a rock on the sensor would be permitted. Familiarity with the characteristics of the machine will enable the operator and inspector to easily distinguish these variations. It might be specified that occasional deviations below the minimum control density of less than 10 ft in length be permissible.

Four examples of using the proposed method to evaluate the density data from the Road Logger are presented. They are: Tehachapi, San Elijo, Barstow, and Salinas, Figures 31, 32, 33, 34. The first two projects had 95 percent relative compaction specified, and the remaining two projects had 90 percent specified.

The minimum control values are derived from the impact data for the respective jobs as shown in Figures 27, 28, 29, 30. These values were multiplied by the specified relative compaction factor, and the calibration correction made. The resulting density is the minimum density permitted for the particular material.

The Road Logger data from Salinas was included, although the sand volume data available did not show the amount of low density material as is shown by the strip charts. This material was taken with the early model Road Logger. The groups of data were originally gathered for different purposes, and it is not known if they are actually compatible. Herein the density information is assumed representative for the purpose of showing the case where there is considerable material which may be below the specified minimum compaction. This illustrates how the locations

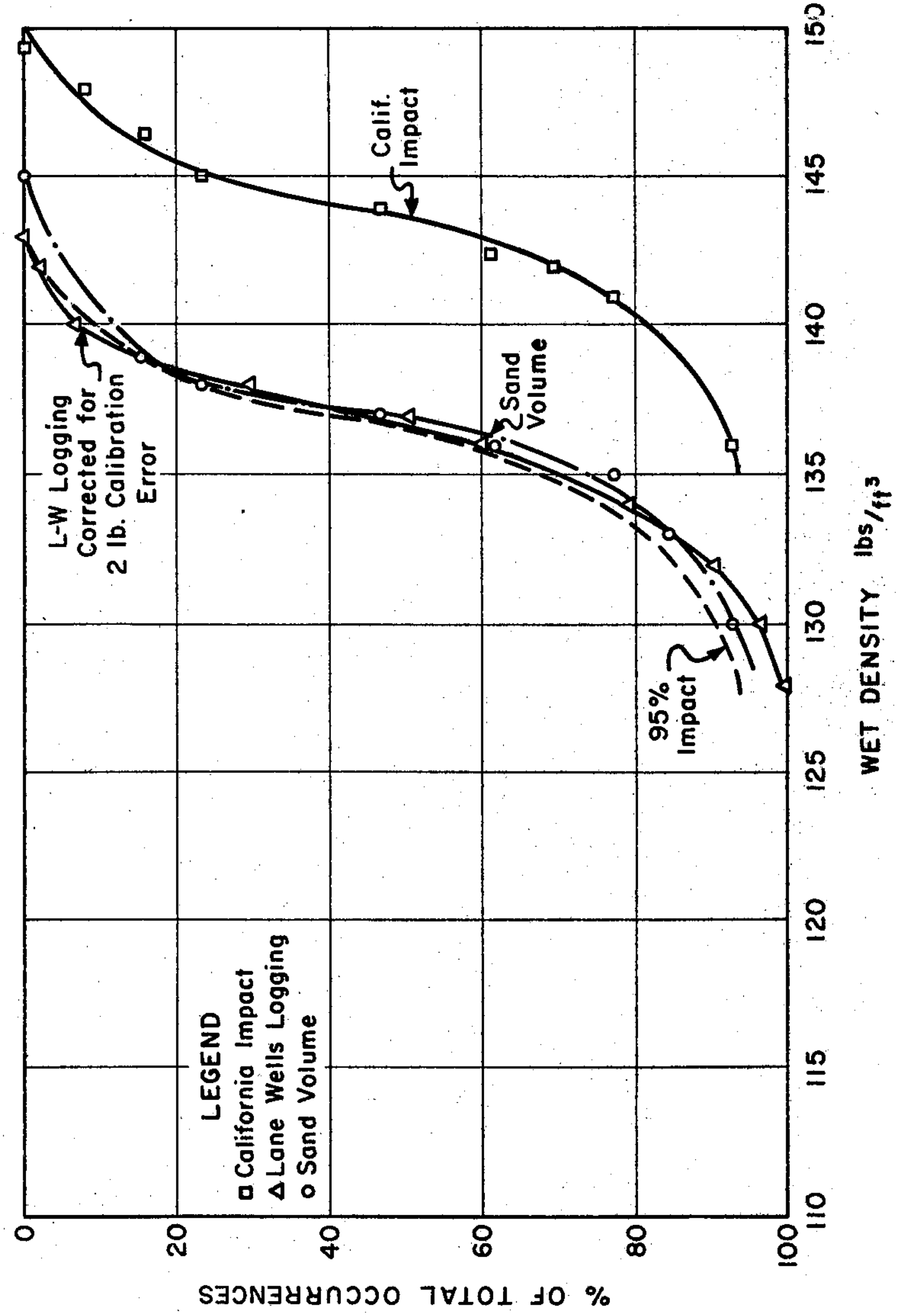
[illegible]

requiring corrective effort could be immediately identified. Furthermore, the limits are clearly defined enabling prompt, efficient corrective effort.

There are several advantages to the concept. The application in the field is simple, easily understood, and instantly applicable. Communication between the inspector and contractors personnel is straightforward. In the laboratory, once the standard for the particular material is established, only as much additional testing is performed as is required to insure that the control value is currently applicable.

[illegible]

FIGURE 23

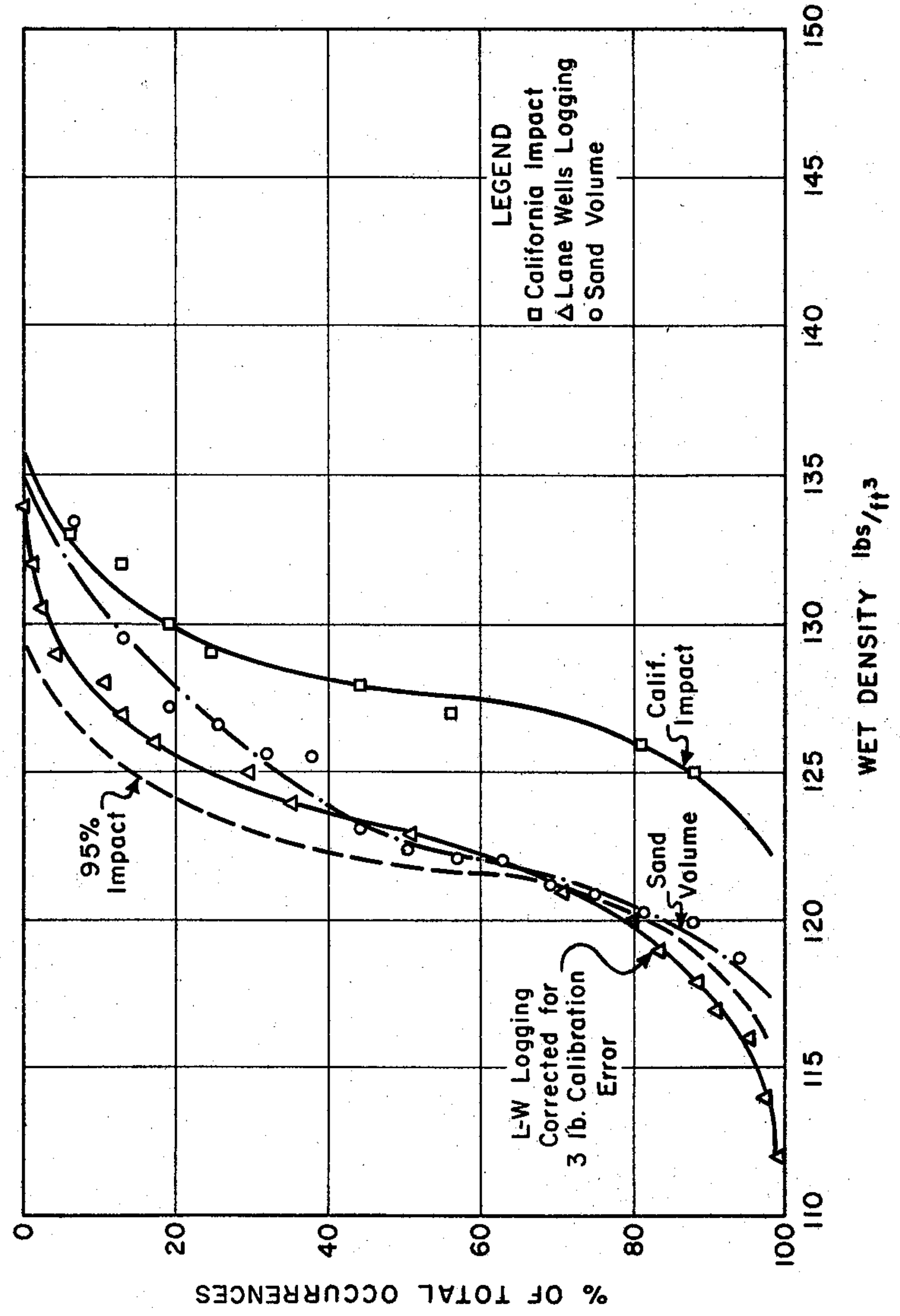


COMPARISON OF WET DENSITY

TEHACHAPI

Sta. 300+25 to 336+50

FIGURE 24

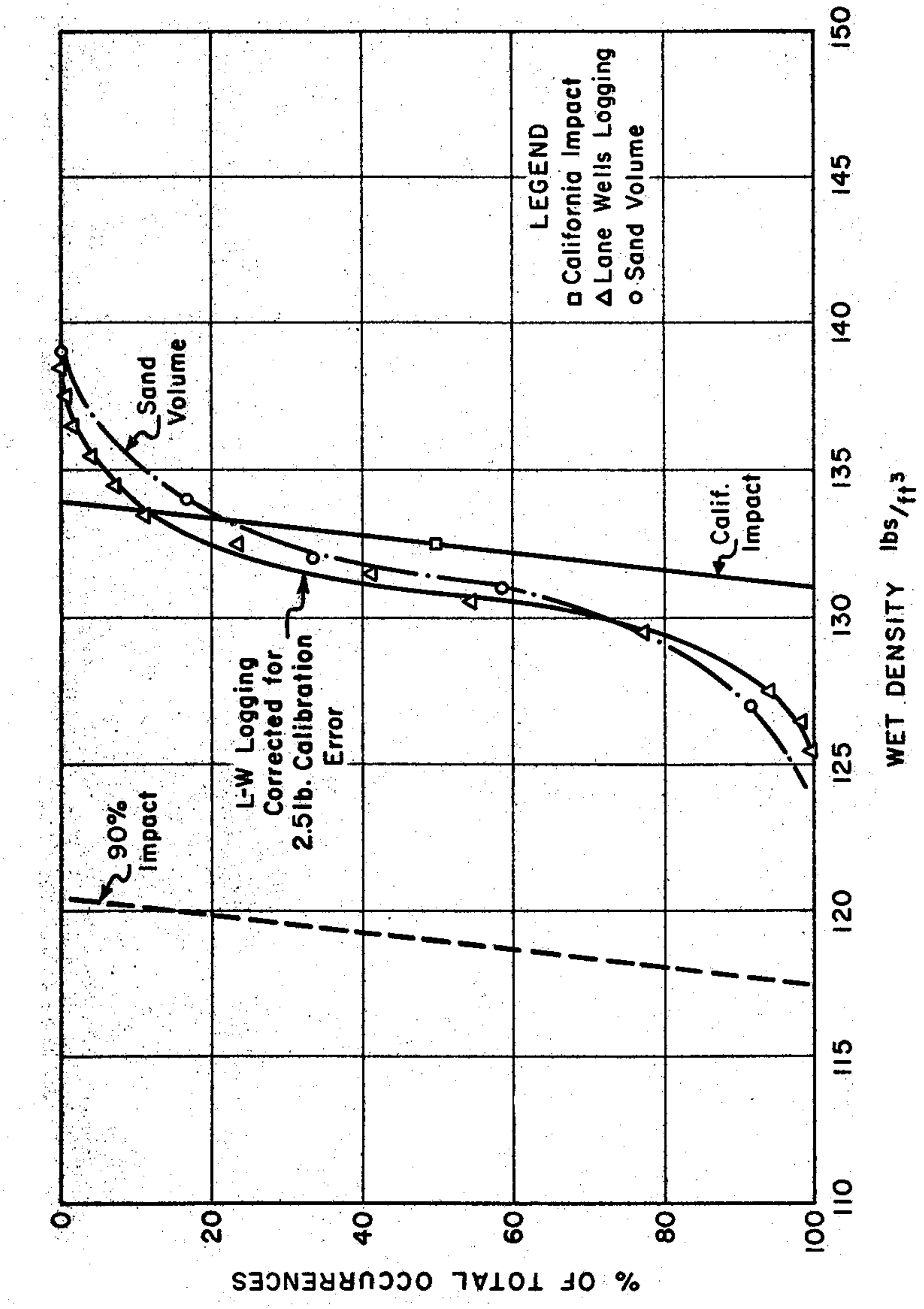


COMPARISON OF WET DENSITY

SAN ELIJO

Sta. 1508+00 to 1550+00

FIGURE 25

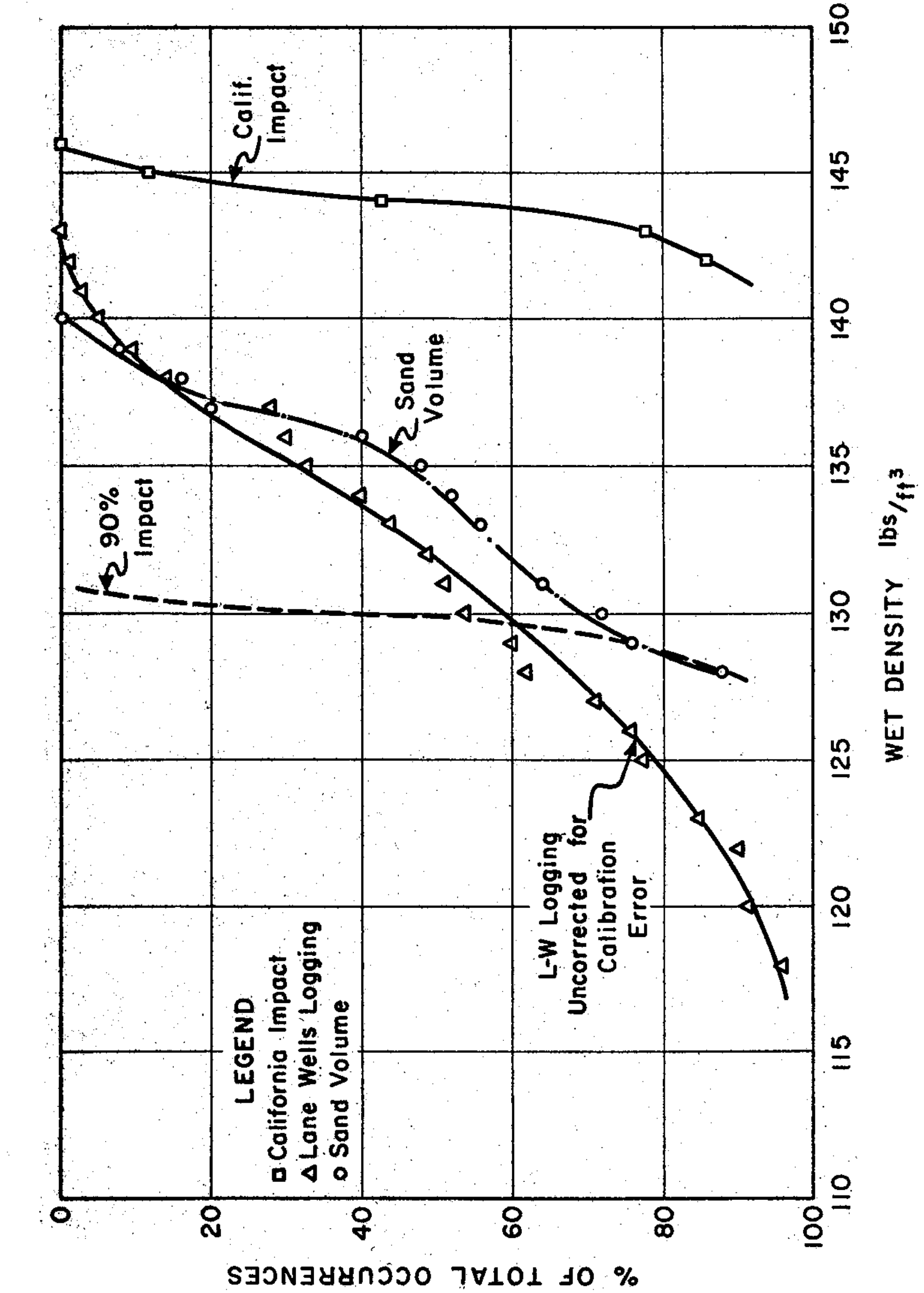


COMPARISON OF WET DENSITY

BARSTOW

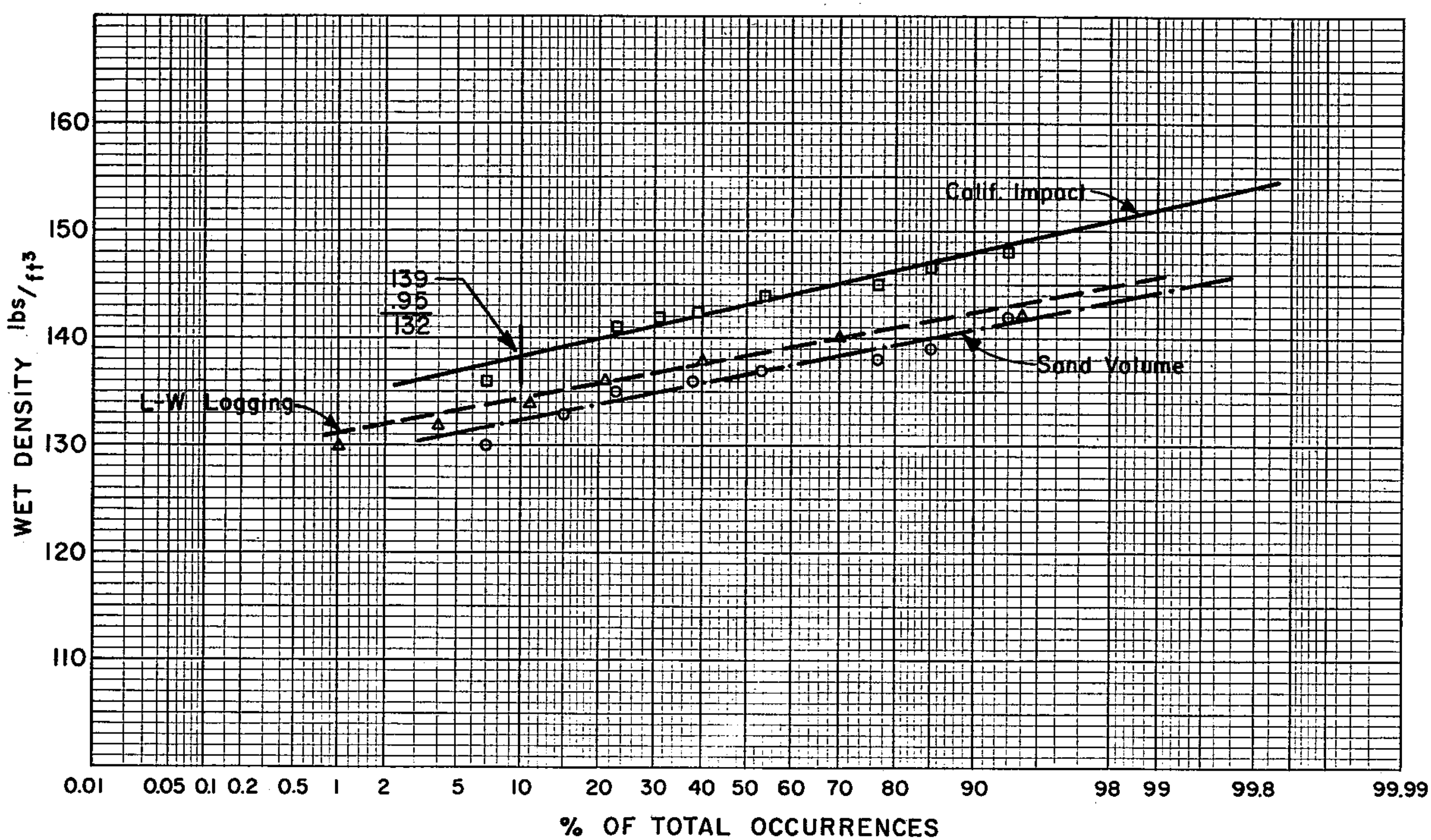
Sta. 248+00 to 330+00

FIGURE 26



COMPARISON OF WET DENSITY
SALINAS

FIGURE 27

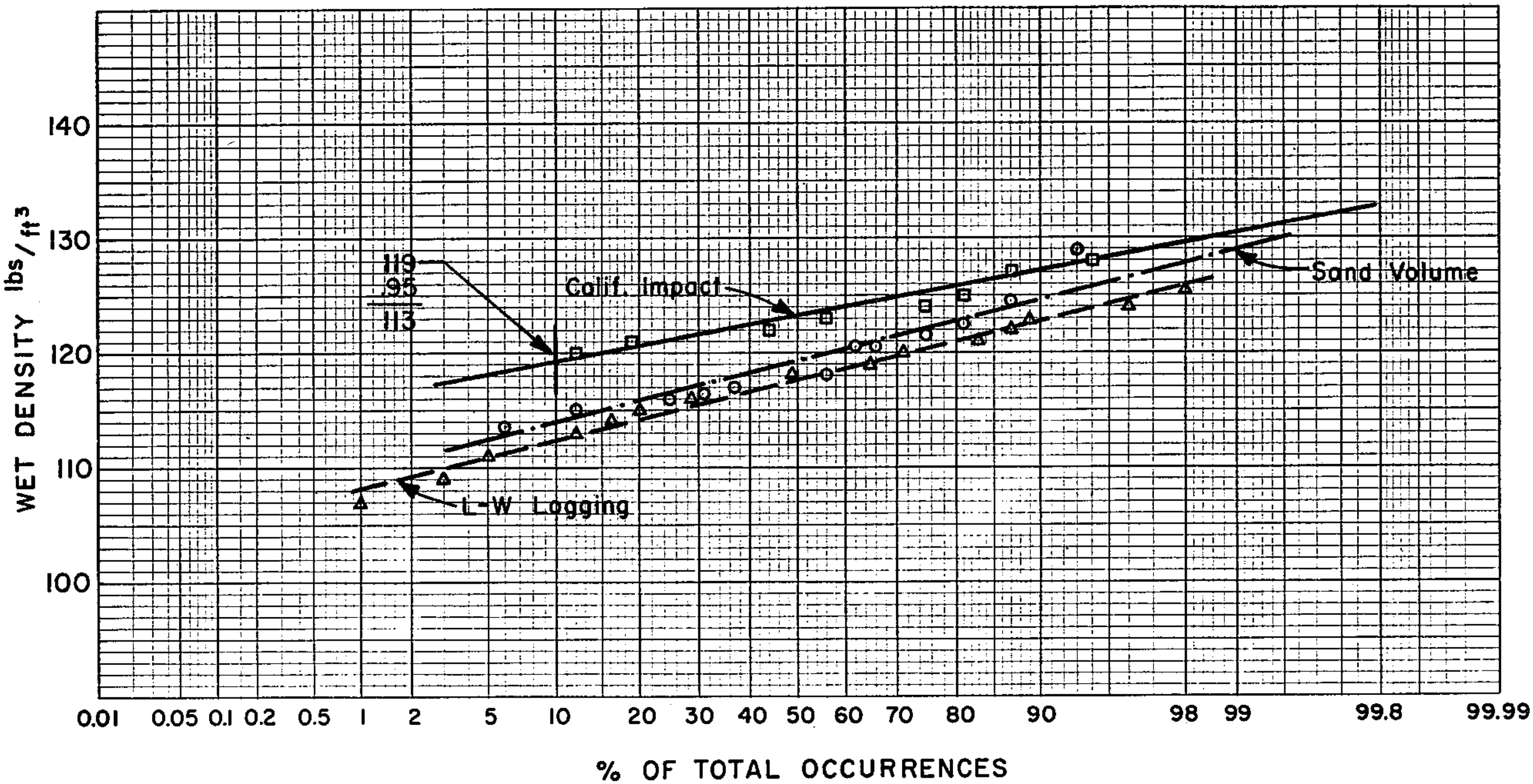


COMPARISON OF WET DENSITY

TEHACHAPI

Sta. 300+25 to 336+50

FIGURE 28

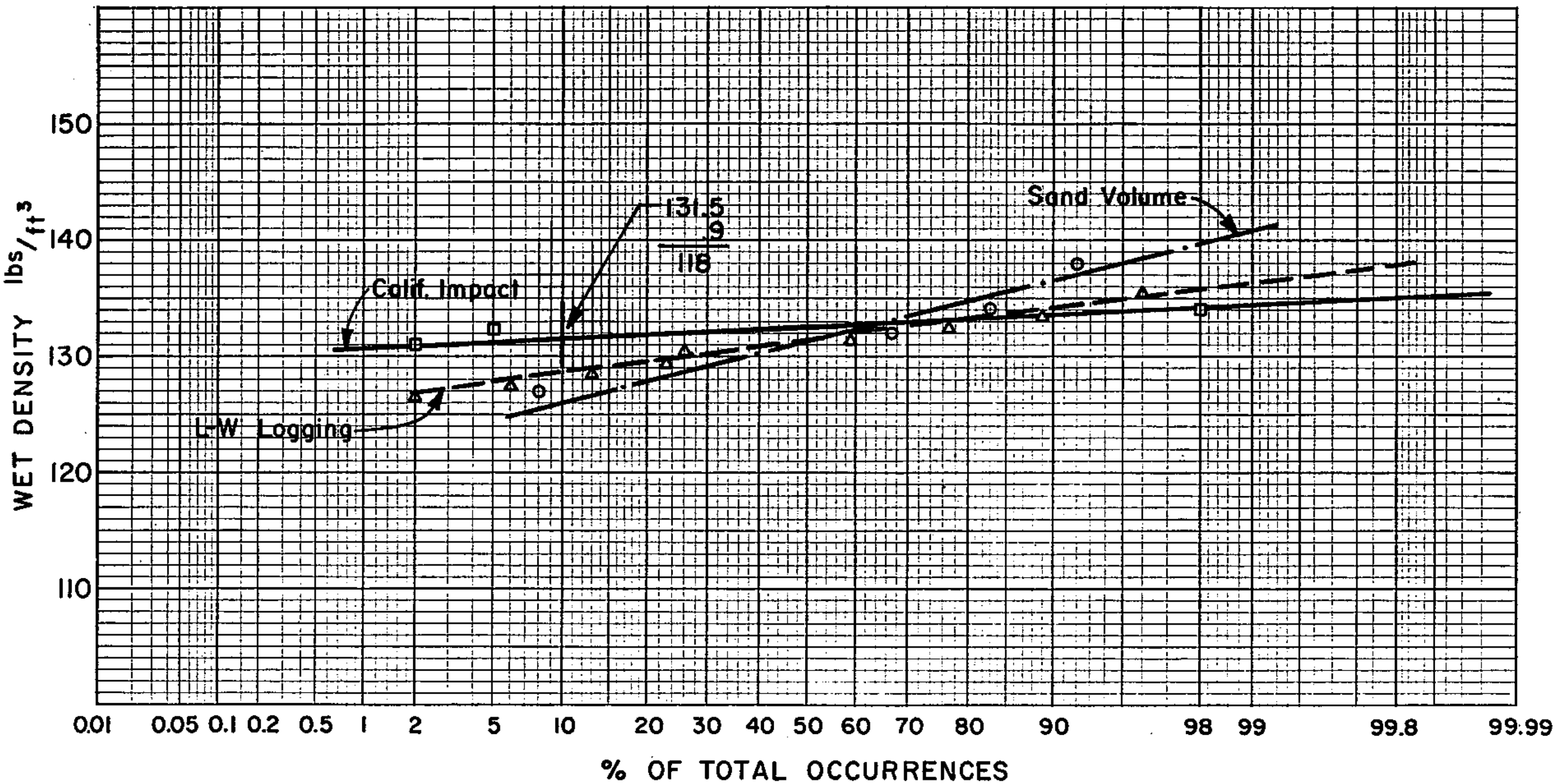


COMPARISON OF WET DENSITY

SAN ELIJO

Sta. 1508+00 to 1550+00

FIGURE 29

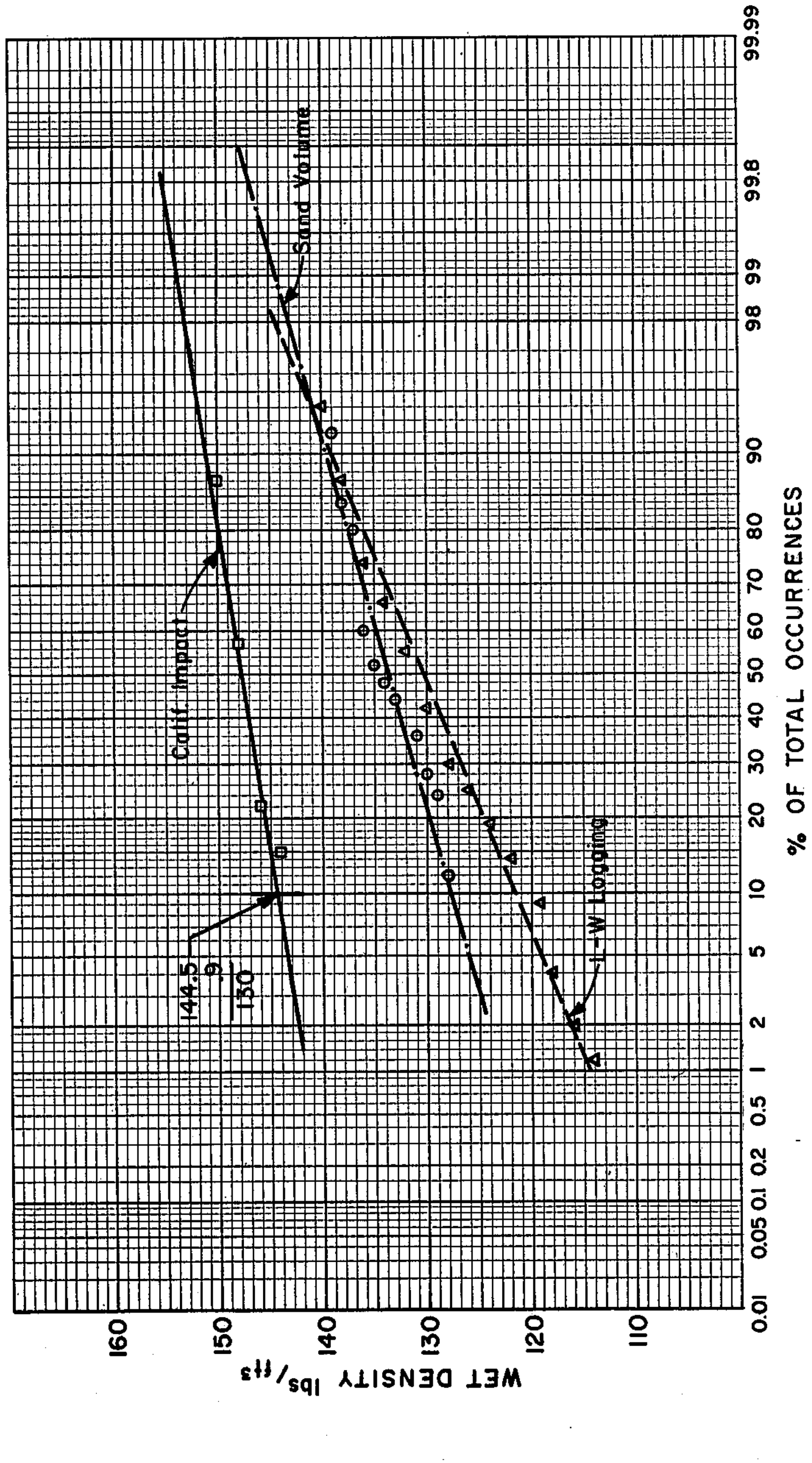


COMPARISON OF WET DENSITY

BARSTOW

Sta. 248+00 to 330+00

FIGURE 30



COMPARISON OF WET DENSITY

SALINAS

District Comment

The Lane Wells evaluation program was conducted with the cooperation of the various Districts. They were asked to comment on the performance of the unit after completion of the field study. These comments were recorded in the form of informal reports, letters, and notes made during conversation with District personnel.

In general the Districts were impressed with the amount of coverage of a job possible with the Road Logger, and the amount of moisture and density data recorded. Special comment was made on the speed with which results were available. The overall feeling was that the unit worked very well on relatively smooth surfaces such as finished subgrade and the structural section. There was favorable comments on the capacity of the Road Logger to point out soft spots and the possible reduction of subsequent settlement with corrective effort. Some of the comments reflected a favorable impression of the accuracy of the Logger, however, there were some that questioned the accuracy of the device.

There was a general agreement in the opinions of District personnel that the Road Logger is restricted in embankment testing, at least with its present equipment. Some concern was expressed over the relative cost of the Road Logger, and its suitability for their particular operations. One remark was made that if used in construction control, any breakdown of the equipment might restrict the progress of the job. The same source also pointed out the possible disadvantage of the greater training required for operating personnel.

APPENDIX

List of Photographs

1. Lane-Wells Road Logger - Model M-1093
2. Lane-Wells Road Logger - Model M-1065
3. Road Logger M-1065 in traveling position
4. Strip chart recorder
5. Electronic contrls
6. Moisture sensor
7. Moisture sensor housing
8. Density sensor
9. Density sensor, close-up
10. Density calibration stone
11. Density sensor housing
12. Density sensor suspension
13. Trailer raised hydraulically
14. Road Logger stuck in desert alluvium
15. View of desert alluvium in which Road Logger got stuck
16. Road Logger stuck on shoulder
17. Stuck on shoulder, front view
18. Stuck on shoulder, rear view
19. Shoulder texture where Road Logger did not get stuck
20. Stuck Road Logger being towed
21. Rut from being stuck
22. Surface too rough for logging
23. Surface too rough for logging
24. Excellent surface for logging
25. Excellent surface for logging
26. Excellent surface for logging
27. Good surface, after blading
28. Good surface, rubber tired roller
29. Fair surface for logging
30. Fair surface for logging
31. Fair surface for logging
32. Troughing effect
33. Poor surface for logging
34. Poor surface, loose
35. Poor surface for logging
36. Poor surface for logging
37. Fair to poor surface condition
38. Logging before blading
39. Logging after blading
40. Typical sand volume site
41. Sand volume holes dug
42. Technique used in repeatability runs
43. Logging near contractor's equipment
44. Logging near equipment
45. Logging near equipment
46. Logging near s[illegible]ding operation
47. Logging and rolling
48. Logging
49. Static reading
50. Hydraulic lift assembly on trailer
51. Depth of measurement study, laboratory
52. Surface roughness study, laboratory

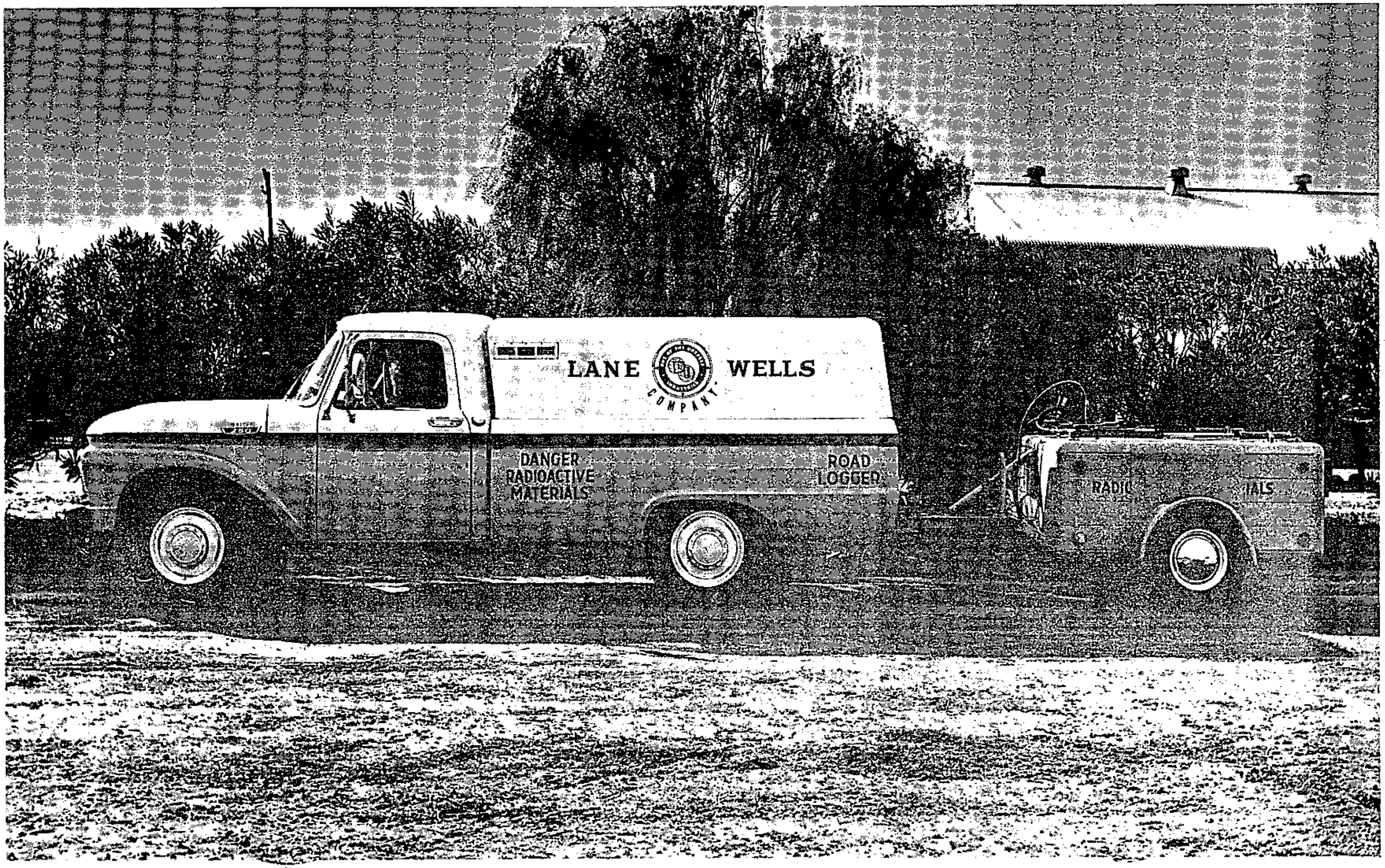


PHOTO 1 Lane-Wells Road Logger Model No. M-1093

PHOTO 2 Lane-Wells Road Logger Model No. M-1065

PHOTO 3 Lane-Wells Road Logger Model No. M-1065
in traveling position

Equipment

PHOTO 4 Inside the cab of the Road Logger showing strip chart recorder in right-center.

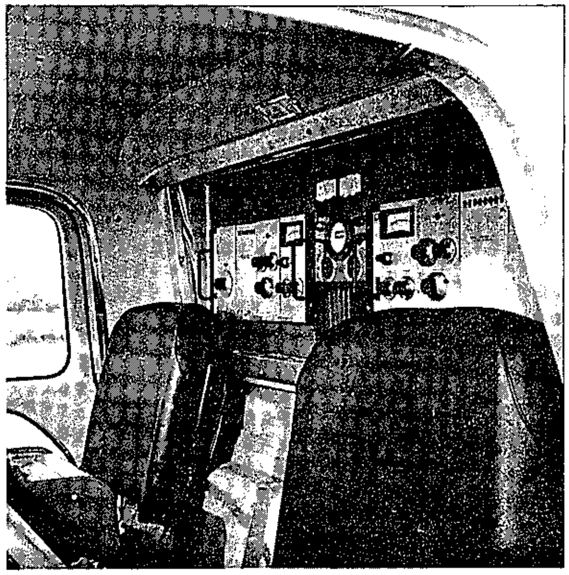


PHOTO 5 Inside back wall of the cab of the Road Logger showing electronics controls.

PHOTO 6 Looking underneath rear of Road Logger truck, with moisture sensor in logging position.

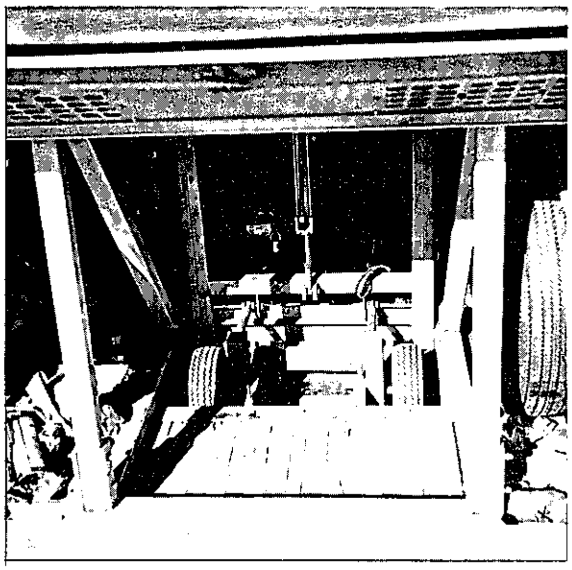


PHOTO 7 Looking into open rear of Road Logger truck, with miosture unit removed.

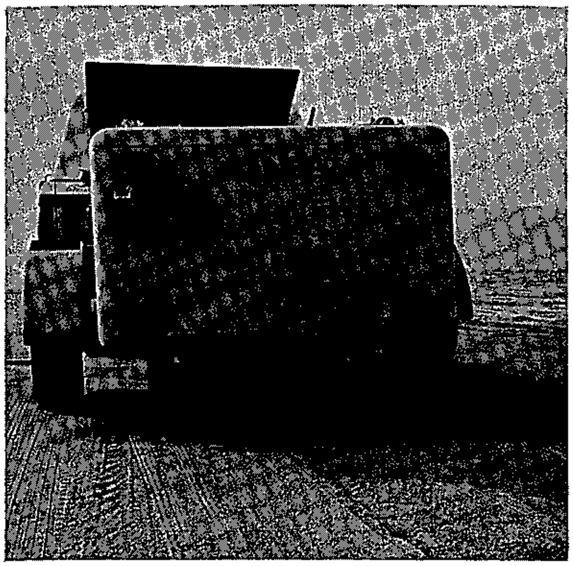


PHOTO 8 Rear view of Road Logger, with density sensor in logging position.

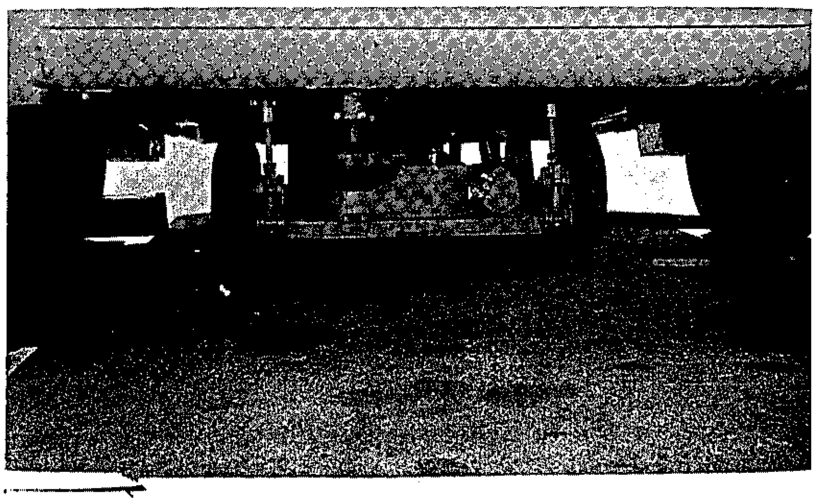


PHOTO 9 Looking underneath Road Logger trailer, showing close-up of density sensor in logging position.

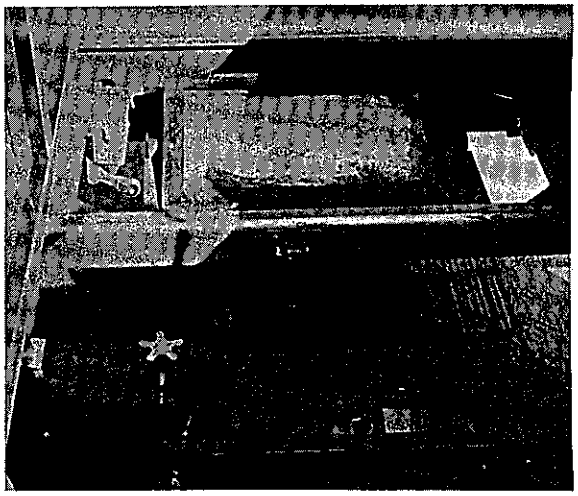


PHOTO 10 Looking down into open trailer, showing density sensor calibration stone (quarried limestone, 135 PCF).

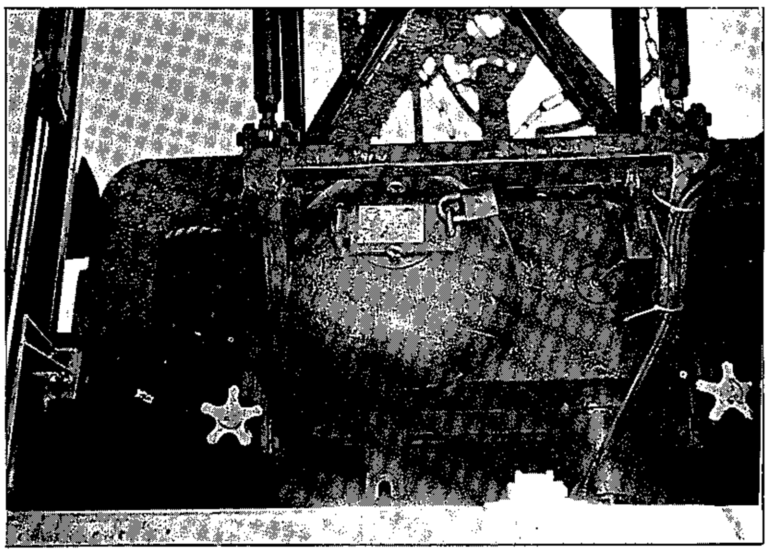


PHOTO 11 Looking down into open Road Logger trailer, showing top of density sensor in logging position.

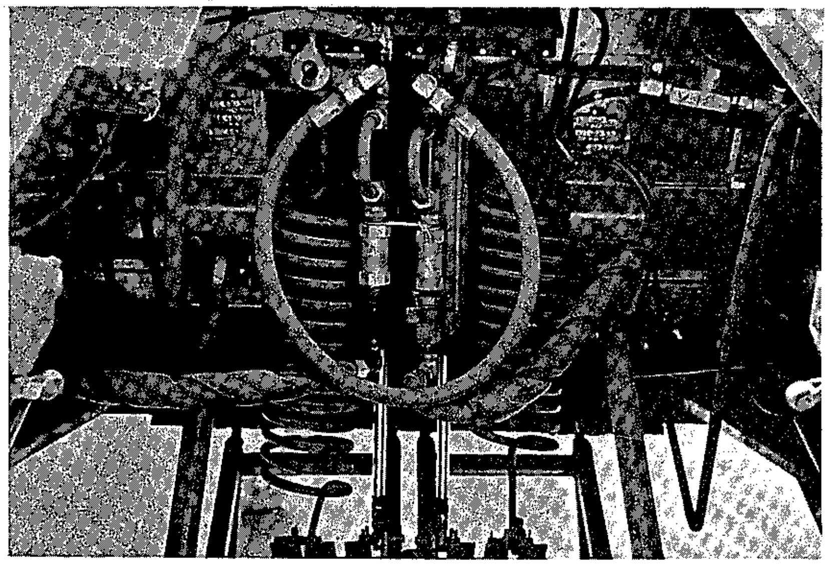


PHOTO 12 Counter-load springs, on the inside wall of the trailer, which support most of the density sensor's weight during logging.

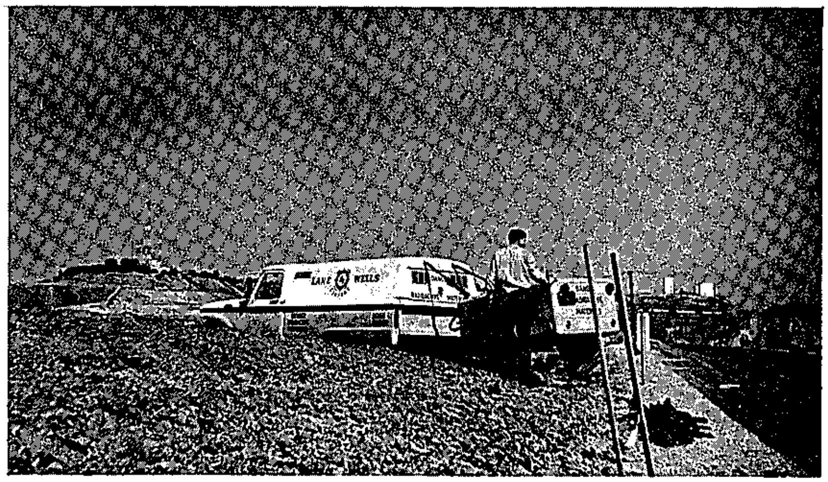


PHOTO 13 The Road Logger trailer is raised hydraulically, to facilitate turning around.

Limitations

PHOTO 14 Road Logger stuck in desert alluvium material.

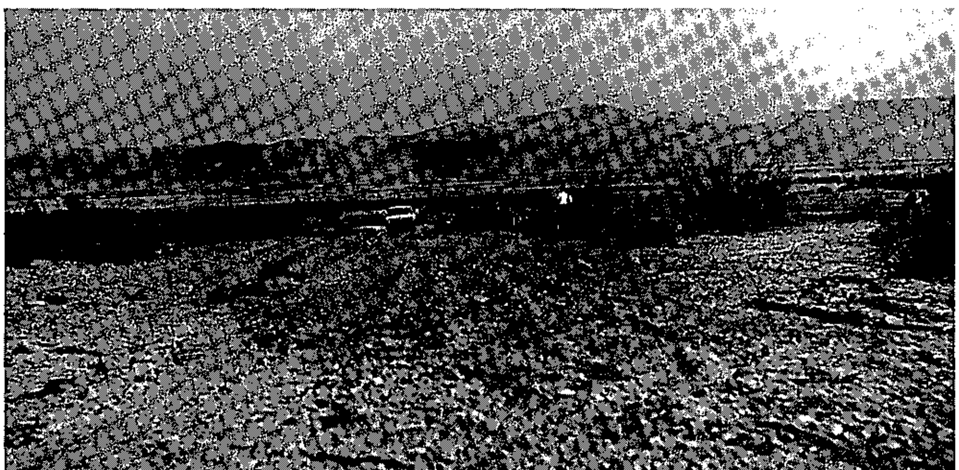


PHOTO 15 View of desert alluvium in which Road Logger got stuck (PHOTO 14).

[illegible]

Limitations

PHOTO 16 Road Logger stuck on shoulder.

PHOTO 17 Front view of Road Logger stuck on loose, sandy shoulder (PHOTO 16).

PHOTO 18 Rear view of Road Logger stuck on loose, sandy shoulder (PHOTO 16).

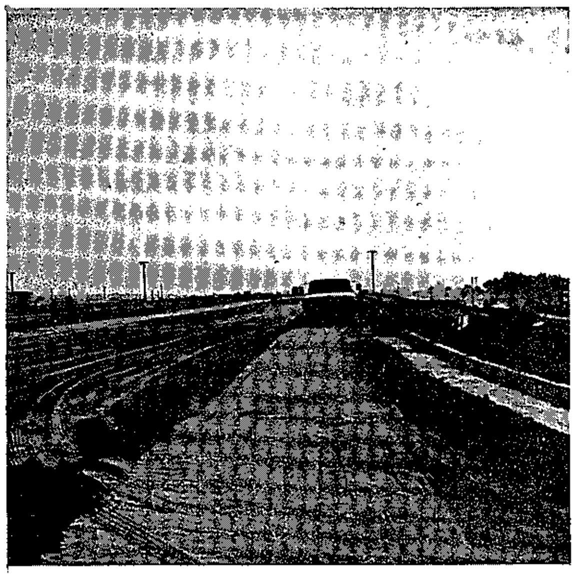


PHOTO 19 View of shoulder in PHOTO 16 where Logger did not get stuck.

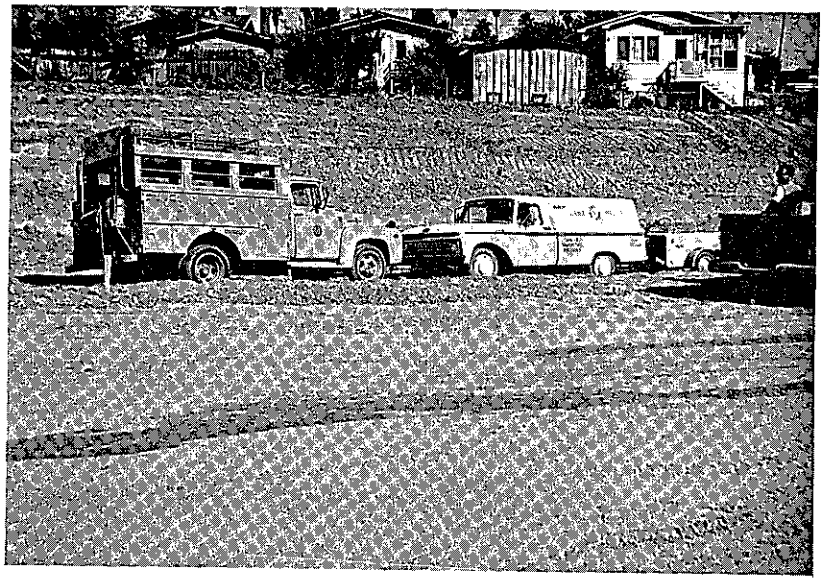


PHOTO 20 Stuck Road Logger being rescued by survey wagon.

PHOTO 21 View of ground condition showing rut after Road Logger was rescued (PHOTO 20).

Limitations

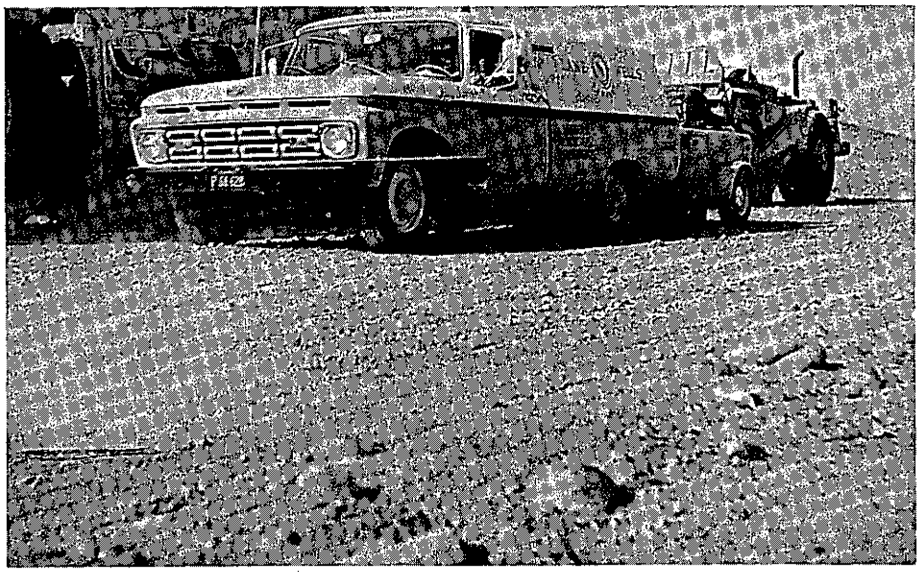


PHOTO 22 Material in foreground is too rough for logging (note large rocks). Material in background is satisfactory for logging.

PHOTO 23 Large rocks in right-center are too rough for moisture probe.

Surface Texture

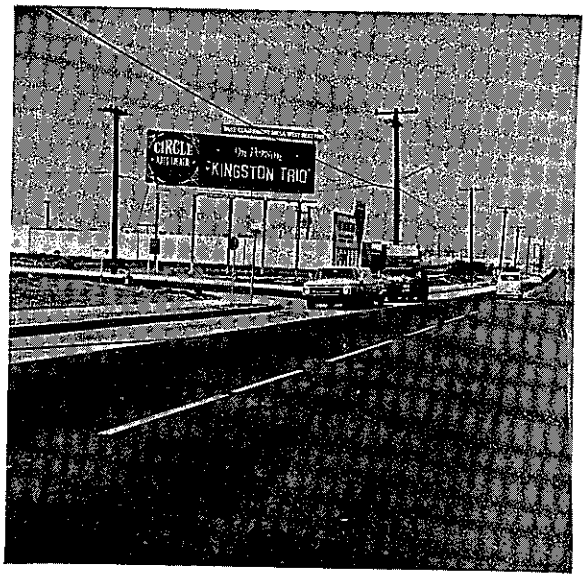


PHOTO 24 Excellent surface (PCCP)

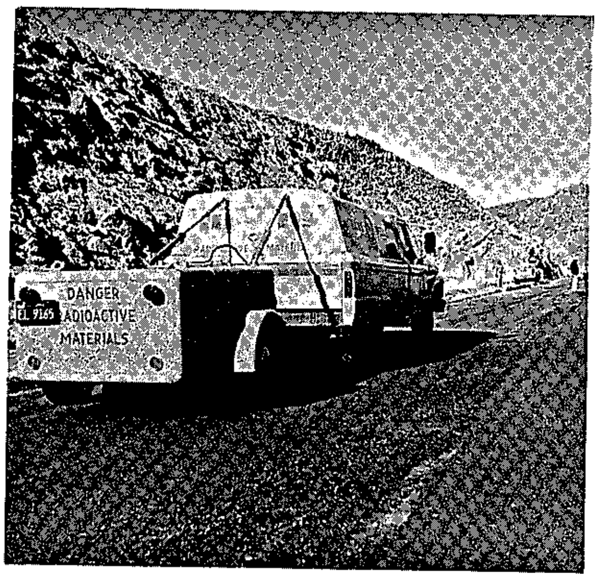


PHOTO 25 Excellent surface (rolled A.B.)

PHOTO 26 Excellent surface, hard, packed, sandy soil.

Surface Texture

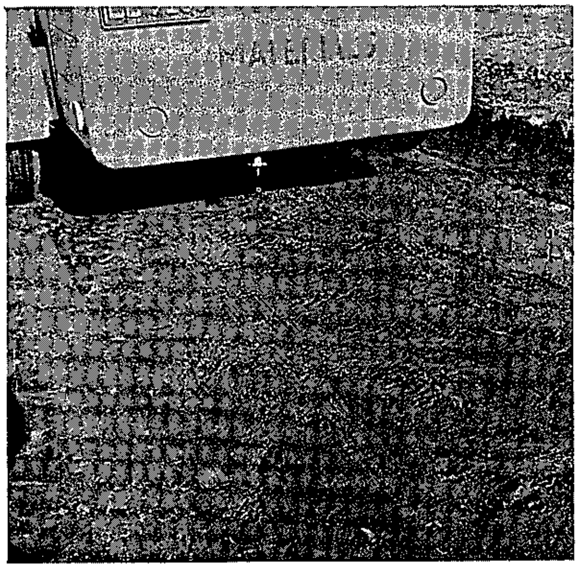


PHOTO 27 Good surface, after blading.

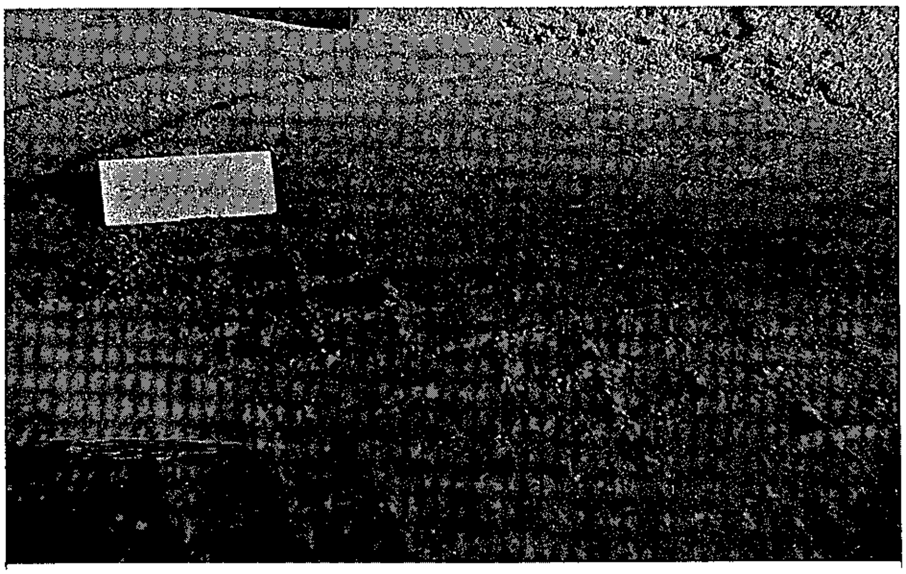


PHOTO 28 Good surface (for logging purposes).

Surface Texture

PHOTO 29 Fair surface texture

PHOTO 30 Fair surface texture

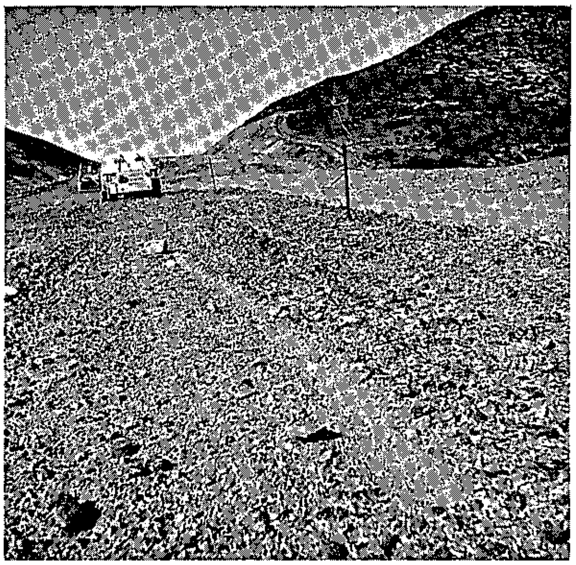


PHOTO 31 Fair surface. Troughing effect was produced by probe dozing large rock (left-center). These rocks (approx. 6 in number) must be removed.

PHOTO 32 Fair surface except for troughing effect. See Fig. 16 for strip chart of this trough.

Surface Texture

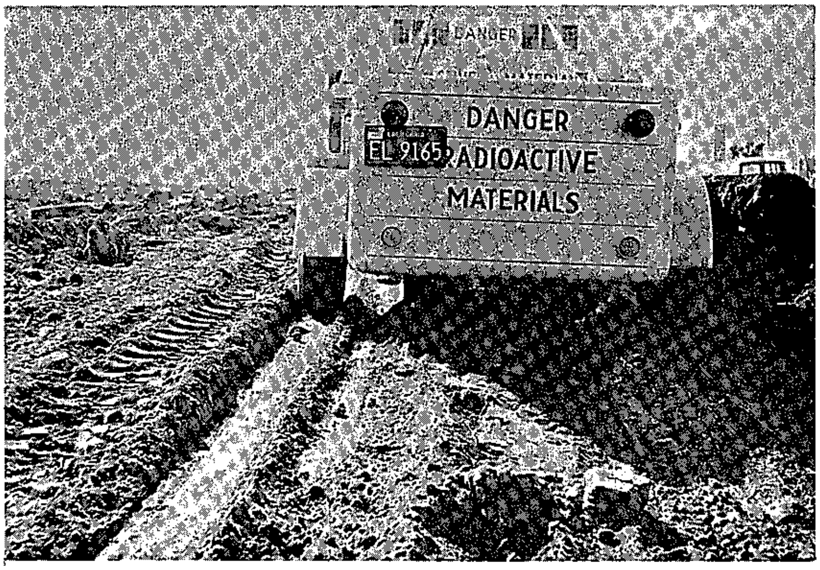


PHOTO 33 Poor surface. Note lack of air gap beneath left side of density sensor.

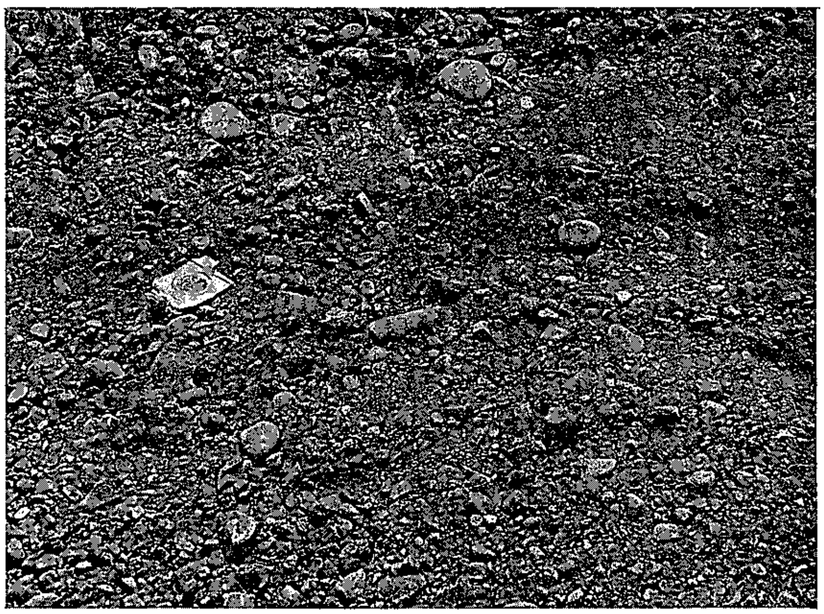


PHOTO 34 Poor surface (too loose).

Surface Texture

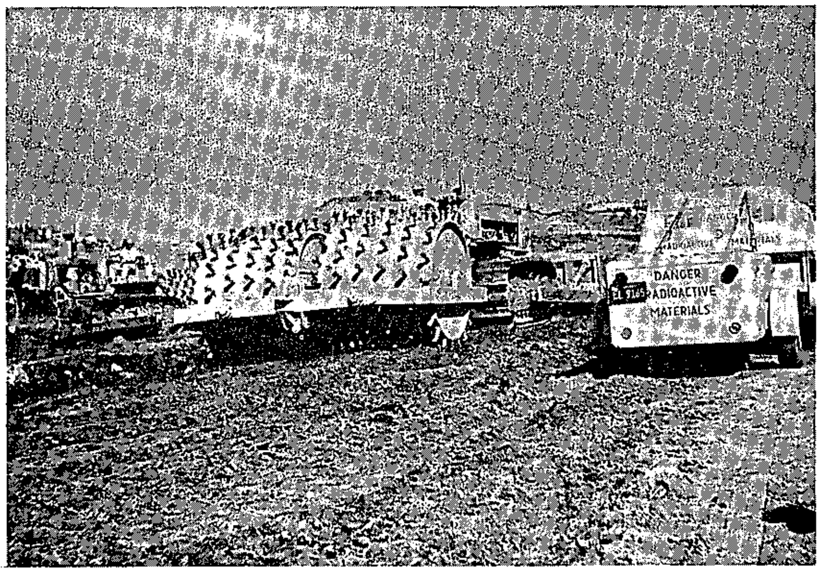


PHOTO 35 Poor surface texture for logging purposes.

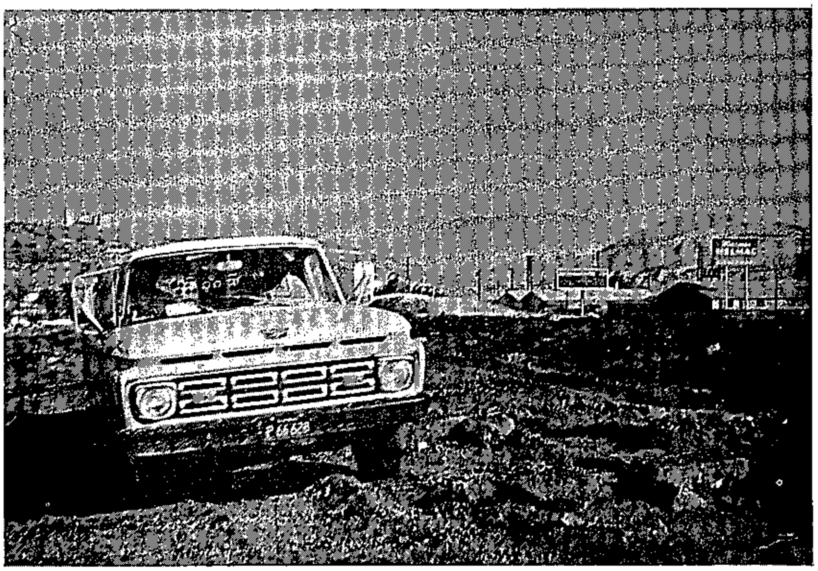


PHOTO 36 Poor surface texture.

Surface Texture

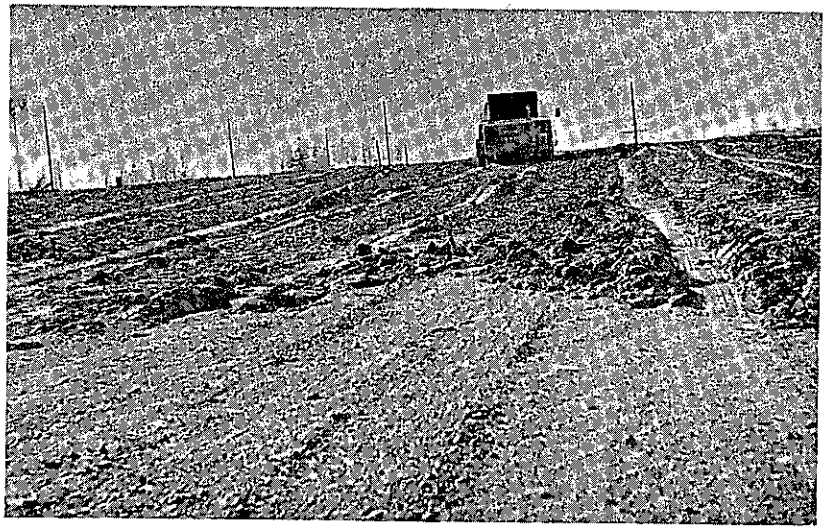


PHOTO 37 Logger traversing an area which changes surface texture from fair to poor.

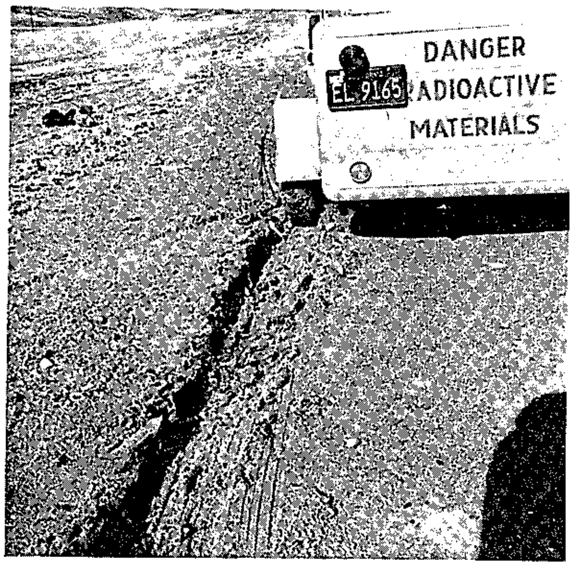


PHOTO 38 Road Logger traversing a course before the blading operation. Fair to good surface texture.

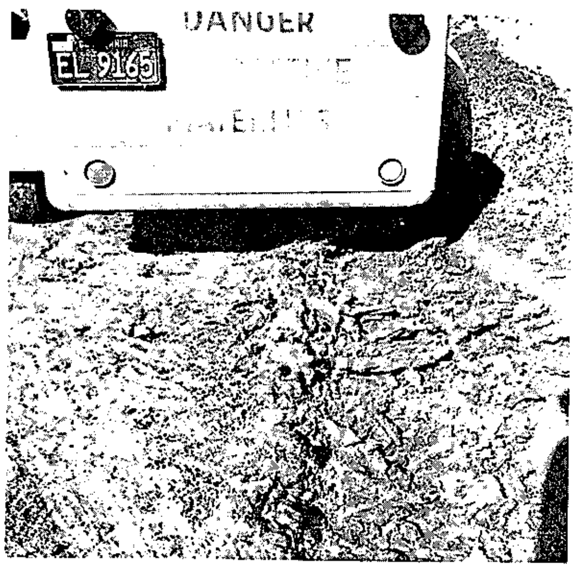


PHOTO 39 After blading operation (PHOTO 38). This is an example where blading decreased surface quality, as it frequently does.

Technique

Sand Volume-Road Logger Correlation

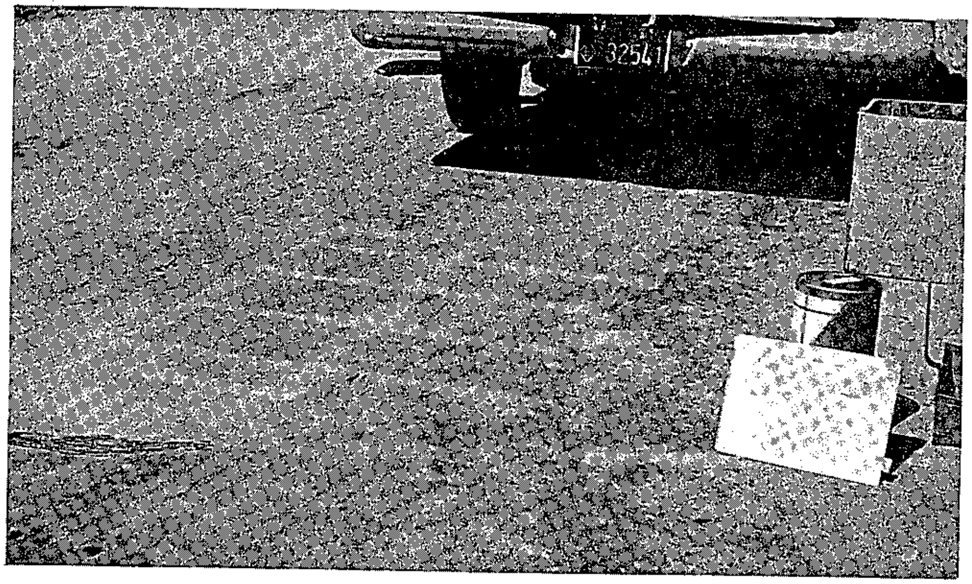


PHOTO 40 Typical sand volume site used for correlation study, before sand volumes were dug. It is outlined by paint configuration. Rectangle measures 2' x 10', with the holes to be spaced 1½' apart.

PHOTO 41 Typical sand volume site used for correlation study, after sand volumes were dug. Before digging, Road Logger static readings were taken over each hole position.

Technique

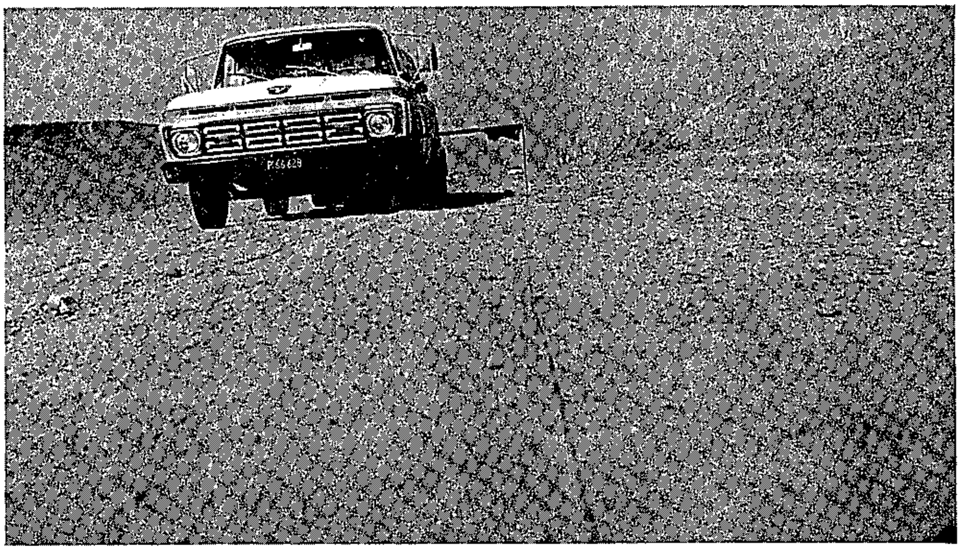


PHOTO 42 Technique used for repeatability and speed change studies. Operator follows the same course repeatedly by dragging a chain along a length of twine which is fastened to the ground.

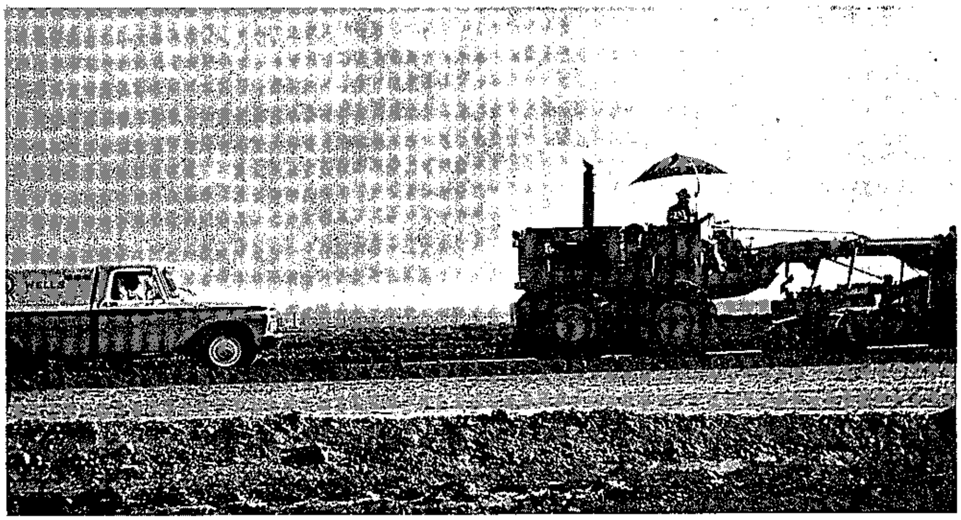


PHOTO 43 Illustration of Road Loggers ability to work near contractors equipment with minimum interference.

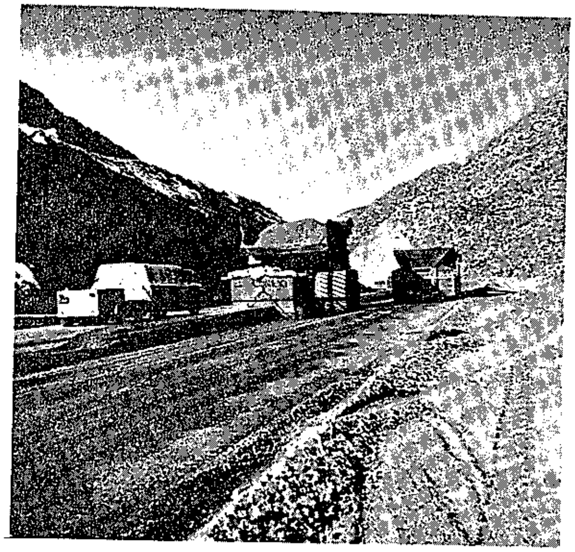


PHOTO 44 Typical logging operation.

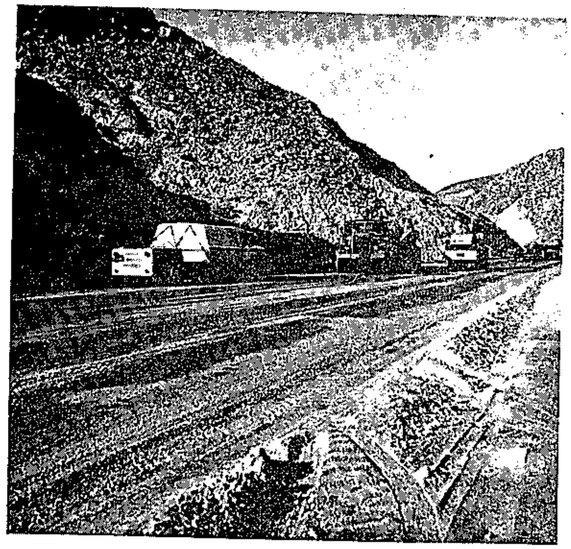


PHOTO 45 Logger working close to contractors equipment, practically no interference.

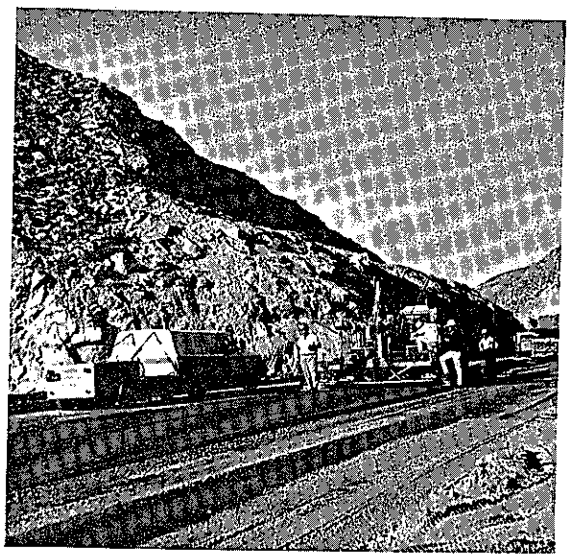


PHOTO 46 Logging and spreading

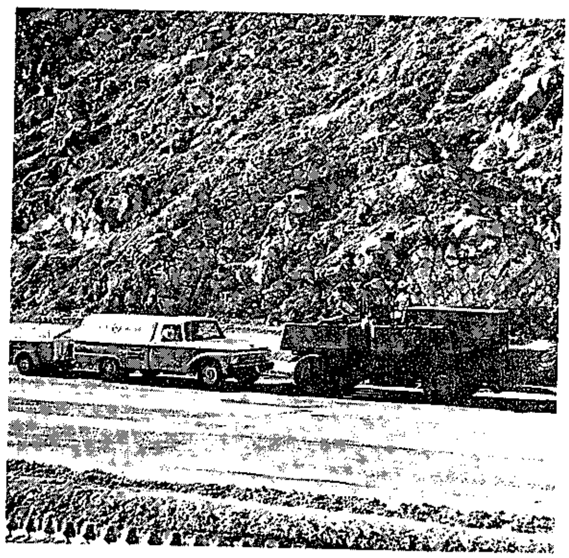


PHOTO 47 Logging and rolling

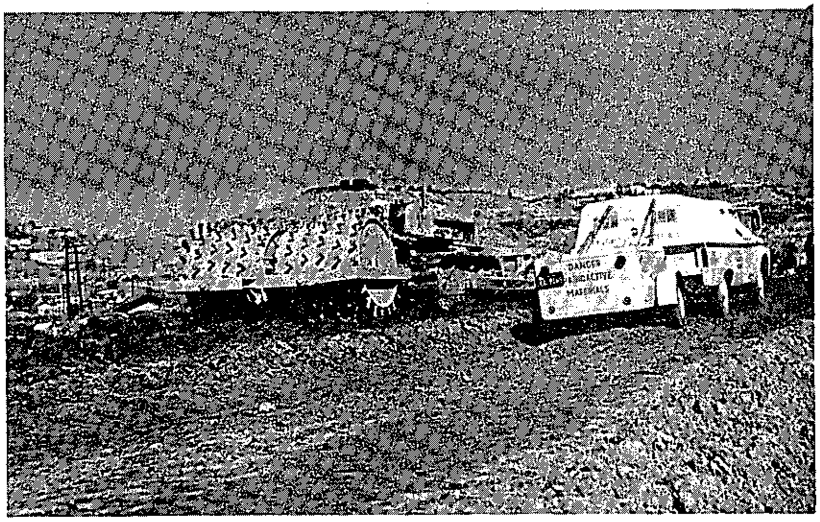


PHOTO 48 Logging on the "new" Pomona Freeway.

PHOTO 49 Static reading for correlation study.

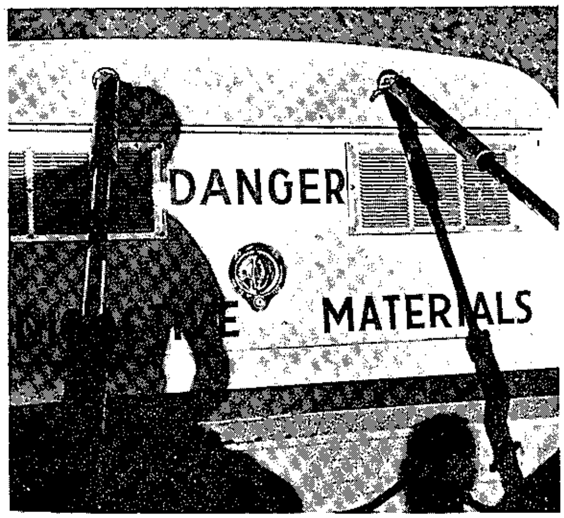


PHOTO 50 Close-up view of hydraulic lift assembly.